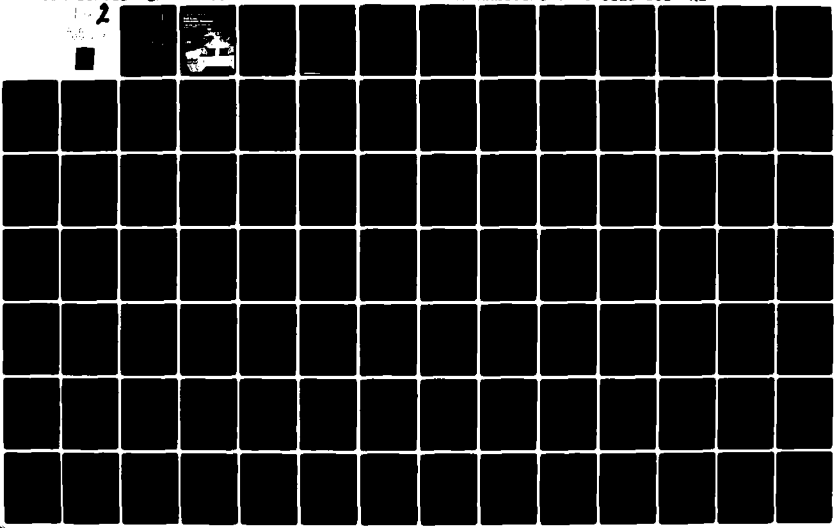
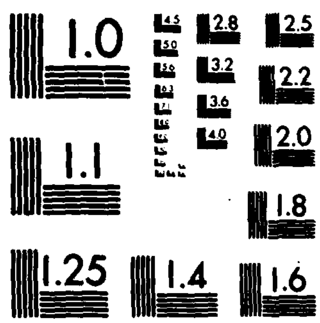
AD-A091 423   SINGER CO   BINGHAMTON NY   LINK DIV   F/G 19/3
DESIGN DEFINITION STUDY REPORT. FULL CREW INTERACTION SIMULATOR--ETC(U)
JUN 78   N61339-77-C-0185
UNCLASSIFIED   LR-895-VOL-2   NAVTRAEQUIPC-77-C-0185-000   NL

1 of 2





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

PHOTOGRAPH THIS SHEET

AD A091423

DTIC ACCESSION NUMBER

III

LEVEL

INVENTORY

Singer Co., Binghamton, NY
Link Div.
Rpt. No. LR-895, Volume II, Final, June 1978
Rpt. No. NAVTRAEQUIPCEN 77-C-0185-0001-2

DOCUMENT IDENTIFICATION

Contract No. N61339-77-C-0185

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	X
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DTIC
ELECTE
S NOV 10 1980 D
D

DATE ACCESSIONED

80 10 28 059

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

[illegible] Requirements

AD A091423

Design Definition Study Report

Full Crew Interaction Simulator

Laboratory Model (FCIS-LM) Device X17B7

prepared for

Naval Training Equipment Center
Orlando, Florida

Link

A DIVISION OF THE SINGER COMPANY

Report No: NAVTRAEQUIPCEN 77-C-0185-0001
LR-895

DESIGN DEFINITION STUDY REPORT

FULL CREW INTERACTION SIMULATOR-LABORATORY MODEL

(DEVICE X17B7)

VOLUME II - REQUIREMENTS

Link Division, The SINGER COMPANY
Binghamton, New York 13902

FINAL
June 1978

Prepared for:
NAVAL TRAINING EQUIPMENT CENTER
Orlando, Florida 32813

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NAVTRAEQUIPCEN 77-C-0185-0001

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
DESIGN DEFINITION STUDY REPORT
FULL CREW INTERACTION SIMULATOR-LAB. MODEL
(DEVICE X17B7)

5. TYPE OF REPORT & PERIOD COVERED
Final
June 1978

6. PERFORMING ORG. REPORT NUMBER
LR-895

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)
N61339-77-C-0185

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Link Division, The SINGER COMPANY
Binghamton, New York 13902

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
NAVAL TRAINING EQUIPMENT CENTER
Orlando, Florida 32813

12. REPORT DATE
June 1978

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
Report consists of twelve sections bound in 7 volumes.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

VOLUME II

TABLE OF CONTENTS

VOLUME II (con't.)

LIST OF TABLES

VOLUME II

LIST OF ILLUSTRATIONS

VOLUME II

SECTION V

5. CREW INTERACTIVE TRAINING REQUIREMENTS

Tables I through V of NTEC Work Statement 2234-016 "Armor Crewman Job Tasks" (reproduced here as figure 5-1 for convenience) lists sequences of tasks normally performed by the crew members on the M60A3 tank. The fundamental theory and basic skills for most of these tasks can be taught without the aid of an FCIS-LM device. However, to reach the levels of proficiency demanded of actual combat, and to develop the interactive crew skills necessary to ensure survival, further rigorous training and practice under similar combat conditions is required.

This section specifies the training objectives and training requirements needed to achieve this goal. In analyzing data for this section, Link has relied heavily upon HumRRO to define specific crew tasks, establish levels of criticality for the various tasks, and also to identify the necessary cue requirements, and determine the ultimate training objectives. This section also reviews and evaluates current tank crew training methods and doctrines in order to provide a baseline reference for FCIS-LM training requirements.

5.1 Current Training Methods

Current tank crew training programs are oriented toward the training of individual skills at the Armor Training Center, with crew integration and crew interaction training taking place in Armor Units in the field. The tables presently used in individual and unit gunnery training have been reviewed to identify the crew tasks in which interaction is of particular importance in tank operations. This analysis was done, primarily through reviews of tactics, procedures and conditions contained in FM 17-12-2, 'Tank Gunnery'. The 'Tank Crew Gunnery Skills Test' of FM 17-12-2 and ARTEP 17-35 were also analyzed to provide information on task criticality and task performance conditions and criteria..

A new training system has recently replaced Basic Individual Training and Advanced Individual Training (Basic Training and Armor Crew Individual Training). The new program, Basic Armor Training, lasts 13 weeks. Graduates of the AIT course were qualified as armor crewmen, but were only familiarized with the driver, gunner, and loader jobs. When assigned to field units as armor crewmen, they receive advanced training in one of those three jobs, frequently starting as loaders or drivers. After a period of unit training, loaders or drivers were trained as gunners and, after extensive experience and formal training became tank commanders.

In the new BAT program, Armor crewmen trained at USATC(A) will graduate as qualified drivers or gunners with working knowledge of other tank crew tasks. When men go on to new unit assignments, they will, as before, undergo a period of systematic unit training. It is expected that the BAT program will provide units

I. ARMOR CREWMAN JOB TASKS - GENERAL

TASK #	TASK DESCRIPTION
4-003	Interpret MBC alarms and markers
4-004	Put on protective mask (connect into gas particulate system)
4-005	Seek cover as protection against NBC hazards
4-012	Protect vehicle interior from CRB agents
9-002	Identify threat and friendly vehicles
9-008	Identify threat and friendly aircraft
11-003	Operate tactical radios/accessories
11-020	Operate vehicular intercommunications equipment
20-025	Operate vehicle under enemy missile (antitank) threat
20-206	Acquire ground targets for tracked combat vehicles
20-314	Prepare a tank for tactical operations
20-382	Perform after firing checks (and services on main gun)
23-212	Report location of enemy mines/minefields
23-313	Identify minefield markers

Figure 5-1 Armor Crewman Job Tasks

II. ARMOR CREWMAN JOB TASKS - DRIVER

TASK #	TASK DESCRIPTION
11-202	Place tank external phone into operation
12-010	Conceal movement by using weather and light conditions
12-011	Conceal movement through route selection
12-014	Conceal movement using smoke
12-203	Select temporary vehicular battlefield positions
20-310	Operate a tank
	(1) React to engine-stall in enemy engagement environment
	(2) Demonstrate ability to operate vehicle on paved surface, crossing a ditch, shell hole, or trench, going over an obstruction, ascending and descending steep grades
	(3) Start engine using slave start procedures
	(4) Back up the vehicle by responding to tank commander directions
	(5) Moving or stopping vehicle during main gun engagement
	(6) Installation and preparation of driver's infrared/night vision sight/periscope
	(7) Operate vehicle in an infrared/night vision environment
20-316	Operate a tank over water obstacles
316-005	Perform before operations maintenance (physical and visual inspection) on the fire extinguishers
316-007	Perform before operations maintenance (physical and visual inspection) on the instruments, gauges, and warning lights

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

316-008	Perform before operations maintenance (physical and visual inspection) on the hydraulic brakes
316-009	Perform before operations maintenance (physical and visual inspection) on the tank controls
316-012	Perform during operations maintenance (physical and visual inspection) on the instruments/ controls
20-363	Start the engine on an M60A3 tank
20-366	Stop the engine of an M60A3 tank
20-376	Operate a tank fixed fire extinguisher (not loaded)
20-381	Perform driver prepare to fire checks
27-210	Prepare and occupy firing positions
27-236	React to/move under direct/indirect fire and enemy aircraft fire

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

III. ARMOR CREWMAN JOB TASKS - LOADER

TASK #	TASK DESCRIPTION
17-308	Clear and load a coaxial MG
17-316-002	Troubleshoot the coaxial MG using the field expedient method
17-319	Boresight a coaxial MG
17-317	Correct malfunctions on a coaxial MG
17-326	Apply immediate action to reduce a stoppage of a coaxial MG
17-319	Mount/dismount a coaxial MG on a tank
20-329	Load the main gun in an M60A3
20-342	Unload misfired main gun rounds
20-380	Perform loader prepare to fire checks
43-002	Stow ammunition

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

IV. ARMOR CREWMAN JOB TASKS - GUNNER

TASK #	TASK DESCRIPTION
11-002	Prepare RT524 and R442 radios and equipment for operation
11-004	Perform operator checks on tactical radios and accessories
17-311	Zero a coaxial MG
17-322	Engage targets with a coaxial MG
20-320-001	Boresight the gunner's telescope and periscope with the main gun
20-320-002	Boresight the gunner's telescope and periscope with the main gun
20-324	Zero the main gun
20-334	Fire the tank main gun
20-337	Engage enemy tank and antitank weapon
20-374	Operate M60A3 auxiliary fire control instruments

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

V. ARMOR CREWMAN JOB TASKS - TANK COMMANDER

TASK #	TASK DESCRIPTION
3-012	Orient a map by comparing features on a map with the ground
3-013	Determine location on the ground by comparing the terrain with a map
3-019	Navigate to point on the ground with a topographic map
3-021	Navigate cross country mounted, using a map
3-102	Maintain orientation in a moving vehicle by comparing terrain with a map
3-204	Navigate cross country mounted, using a map
4-015	Direct unmasking procedures
11-113	Prepare speech security equipment TSEC/KY-38
11-213	Prepare speech security equipment TSEC/KY-8
17-010	Zero an M85 MG
17-012	Boresight an M85 MG
315-002	Troubleshoot the M85 MG using the field expedient method
315-318	Clear and load an M85 MG
315-321	Engage targets with an M85 MG
315-325	Apply immediate action to reduce a stoppage of an M85 MG
315-328	Mount/dismount an M85 MG
18-004	Conduct crew drill
20-204-001	Prepare a range card for a tank
20-204-002	Prepare a range card for a tank

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

20-202	Issue a fire command for a tank
20-338	Apply misfire procedures in case of main gun failure to fire
20-346	Employ the tank searchlight
20-350	Boresight a tank mount searchlight
26-002	Select targets appropriate for attack
26-003	Call for supporting fire
26-004	Adjust supporting fire
26-007	Terminate a supporting fire mission
27-105	Coordinate organic and supporting fires
27-110	Engage aircraft with individual and crew-served weapons
27-216	Select firing positions
27-218	Select targets
27-219	Designate targets
27-224	Select alternate and supplementary positions
27-229	Conduct mounted tactical movement
29-201	Adjust supporting fire (mortars)

Figure 5-1 Armor Crewman Job Tasks (Cont'd)

with crewmen more qualified in the crucial crew skills, and permit the unit to more rapidly develop combat-qualified crews. The current program,both in the Armor Training Center and in field units both in the United States and Europe,is severely constrained by the availability of terrain and the cost of tanks, fuel, ammunition, and other facilities required for developing proficiency levels vital to combat readiness. The current training program, including individual and platoon-level gunnery tables is an excellent program for training drivers, loaders, and gunners in performing their own individual tasks, but the program is unable to provide the level and variety of training required to qualify the crew and the tank commander for tactical operations.

5.2 FCIS Training Objectives

The M60A3 is capable of fighting effectively in almost any type of terrain it could encounter in North America or in Central Europe. Its range and mobility, even with minimal logistics support, permit it to be involved in a wide variety of terrain and tactical situations in a very short period of time. In addition, it can effectively engage any target it might expect to encounter on any battlefield in the foreseeable future. These capabilities were developed to make the M60A3 an unusually versatile and effective weapons system. At the same time, they impose stresses and skill requirements on the crew, particularly in the integration of individual performances, which are unequalled in any modern weapon system. Table 5-1 lists over three hundred and fifty distinct types of engagements the M60A3 crew must be able to handle. This table does not allow for varieties of terrain, visibility, or threat concealment with which the crew will be faced in combat; nor does it consider the impact on the crew, in all of these situations when a crewmember is missing. It also fails to express the conditions of stress under which these engagements must be fought, time pressures on the crew in each engagement, in maintaining efficiency from one engagement to another, and the demands of simultaneous engagements. Clearly, no training program depending on real-world ranges and tactical exercises, can provide adequate training in even the most critical crew tasks; the combination of significant events quickly exhausts the terrain, ranges, targets, personnel, tanks, ammunition and facilities available.

Individual crew skills required for the operation of the M60A3 and its systems are not especially difficult to learn, with the exception of individual tactical driving skills, given the time to perform them as fixed operating procedures. Task difficulty and criticality arise, not from the complexity of the tasks, but in applying task procedures in tactical settings. In the tank, no individual task is performed in isolation; each task, to be effective, requires the participation of two, three,or four individuals with each task inevitably influencing the subsequent performance of each member of the crew. In

addition, many critical performances, and the decisions initiating them, are made in from one to ten seconds. In effect, crew interaction training problems arise in finding settings in which individual crew members can practice under conditions of time pressure and stress, with rapidly changing tactical situations.

As a result of the analysis performed for section 4 and in studying the current training methods, a series of scenarios was developed. These scenarios, summarized in table 5-1, incorporate exercises contained in Tables VIII A and VIII 13, and indicate the integration of crew activities in the kinds of day and night engagements in which the M60A3 tank may be involved.

5.2.1 M60A3 Tank Scenarios.

General Situation:

The First Battalion 201st Armor which is part of a larger force has been given the mission to attack to the south and seize the town of New Hampton. The plan of attack provides for Company A and B attacking abreast. Company A is attacking on the left with the first, second and third platoons abreast. The second platoon will attack in a wedge formation. Tank number 23 will be the leading tank of the platoon. NBC protective equipment will be worn.

Special Situation:

Before leaving the assembly area and moving to the attack position, pre-combat checks were performed by the four crew members of tank number 23. The boresight and zero of all weapons has been checked, the loading of the machine guns has been accomplished, the stowage of all ammunition has been checked, all communications systems are operational and the turret has been placed in power operation to include the stabilized (stand by) mode for firing.

As the tank crosses the line of departure, the tank commander and loader are unbuttoned and are scanning the foreward area attempting to locate and identify targets, the gunner is looking through his periscope and is prepared to lay the main gun on any target so designated by the commander. The driver is maintaining a steady speed, is trying to avoid obstacles and ditches, is trying to minimize directional change, and is prepared to alert the rest of the crew if any of the above cannot be maintained. The tank commander has just monitored a transmission over the platoon net, that another tank in the platoon has just destroyed an enemy tank on the right flank.

First Engagement:

AT that time the tank commander observes what appears to be

TABLE 5-1 SCENARIO INDEX FOR M60A3 TANK, BASED UPON TABLE VIII A AND B (TWENTY ENGAGEMENTS) STABILIZED MODE

ENGAGE-MENT	TANK MODE	TARGET DESCRIPTION	TYPE ENGAGEMENT	RANGE	ILLUMI-NATION	OTHER
1	MOVING TANK	TANK FRONT SHOT	BATTLESIGHT HEAT	900 METERS	DAY	
2	MOVING TANK	MOVING TRUCK	CAL 50	700 METERS	DAY	
3a	MOVING TANK	MOVING TANK	BATTLESIGHT	1200 METERS	DAY	MULTIPLE
3b	MOVING TANK	MOVING TANK	APDS	1600 METERS	DAY	ENGAGE-MENT
4	MOVING TANK	TROOPS	COAX	600 METERS	DAY	
5	STATIONARY TANK	ANTITANK	PRECISION TELESCOPE HEP	1600 METERS	DAY	
6	MOVING TANK	HELICOPTER	CAL 50	900 METERS	NIGHT	
7	STATIONARY TANK	TANK FRONT SHOT	BATTLESIGHT HEAT	1000 METERS	NIGHT	THERMAL SIGHT
8	STATIONARY TANK	TROOPS	CAL 50	1200 METERS	NIGHT	THERMAL SIGHT
9	STATIONARY TANK	TANK FRONT SHOT	PRECISION ADPS	1800 METERS	NIGHT	THERMAL SIGHT
10	MOVING TANK	SUSPECTED TARGET	SUPPRESSIVE FIRES LOADERS MG	100 METERS	NIGHT	
11	MOVING TANK	HELICOPTER ATGM	CAL 50	1000 METERS	DAY	EVASIVE MOVES
12	STATIONARY TANK	TANK FRONT SHOT	PRECISION ADPS	1900 METERS	DAY	SIMUL-TANEOUS WITH ENGAGE-MENT 13

TABLE 5-1 SCENARIO INDEX FOR M60A3 TANK, BASED UPON TABLE VIII A AND B (TWENTY ENGAGEMENTS) STABILIZED MODE (CONT'D)

ENGAGE-MENT	TANK MODE	TARGET DESCRIPTION	TYPE ENGAGEMENT	RANGE	ILLUMI-NATION	OTHER
13	STATIONARY TANK	TROOPS	CAL 50	1500 METERS	DAY	SIMUL-TANEOUS WITH ENGAGE-MENT 12
14	MOVING TANK	TANK FRONT SHOT	BATTLESIGHT HEAT	800 METERS	DAY	
15	MOVING TANK	SUSPECTED TARGET	SUPPRESSIVE FIRES COAX	500 METERS	DAY	
16	MOVING TANK	TANK FRONT SHOT	BATTLESIGHT HEAT	800 METERS	NIGHT	THERMAL SIGHT
17	MOVING TANK	MOVING TRUCK	COAX	700 METERS	NIGHT	THERMAL SIGHT
18a 18b	MOVING TANK MOVING TANK	TANK FRONT SHOT TANK FLANK SHOT	BATTLESIGHT ADPS	1300 METERS 1500 METERS	NIGHT THERMAL SIGHT	MULTIPLE ENGAGE-MENT
19	MOVING TANK	TROOPS	COAX	600 METERS	NIGHT	THERMAL SIGHT
20	STATIONARY TANK	ANTITANK	PRECISION TELESCOPE HEP	1500 METERS	NIGHT FLARE	

the turret of an enemy tank in hull-defilade to his direct front at a range of 900 meters. The tank commander, prior to crossing the line of departure, had anticipated enemy tanks to be his greatest threat. He had therefore prepared his tank for a battlesight engagement by having a round of HEAT loaded in the main gun and HEAT ammunition indexed. Upon sighting the enemy tank, the following actions are taken by the members of tank 23. The tracer element is followed by the eye and the round is observed hitting the enemy tank. The tank commander announces "TARGET." He then directs the driver to move out. Shortly after directing the driver, the tank commander observes an enemy truck moving along a road to the front.

Second Engagement:

The target appears to be at an estimated range of seven hundred meters. The tank commander decides that the 50 caliber machine gun is the proper weapon to use. He alerts the crew by announcing "CALIBER 50." After estimating the range, he uses the ballistic reticle to insure the first burst is in the target area. He uses the low rate of fire, firing bursts of 10-15 rounds using 2-3 tracers. He adjusts for elevation using the manual elevation handle and tracks the truck for deflection using the TC override. The driver continues to move the tank at a constant rate of speed while attempting to provide a stable tank from which to fire. The tank commander observes the enemy truck burst into flames and he ceases fire after firing about 50 rounds. The Tank Commander announces "END OF MISSION."

Third Engagement:

Tank number 23 continues on his mission as the lead tank in the platoon. Upon reaching the crest of a hill, the tank commander halts the tank on the reverse slope in a defilade position and observes to his front to determine the location of possible enemy positions. The open rolling country to his front indicates that possible targets would appear at ranges of 1,000 meters to 2,000 meters. The tank commander therefore directs the gunner and loader to prepare for a battlesight utilizing APDS ammunition. APDS is loaded and is indexed. As the tank commander surveys the area he, observes two enemy tanks moving from left to right. One enemy tank is to the direct front at an estimated range of 1,200 meters and the other enemy tank is to the right-front at an estimated range of 1,600 meters. The following actions take place:

First Engagement:

Fire Command Element	Tank Commander	Gunner	Loader	Driver
"Gunner Battlesight"	Lays gun for direction	Ensures turret power is on.	Checks the turret ring and ensures turret is not locked	Continues to move forward and attempts to orient hull.
"Tank"		Ensures Appropriate switches are on.	Ensures path of recoil is clear and safety switch is on "FIRE"	
"Direct Front"	If needed talks gunner into target area.	Traverses turret in search of target and announces "IDENTIFIED"	Announces "UP" and is prepared to load next round if required	
"Fire"	Assumes position to sense round to be fired	Aims at base of target, announces "ON THE WAY" and fires.	Braces	Prepares to sense round.

Fire Command Element	Tank Commanders	Gunner	Loader	Driver
"GUNNER BATTLESIGHT"	Lays gun for direction.	Ensures turret power and appropriate switches are on.	Checks the turret ring and ensures turret is not locked	Continues to move forward attempts to orient hull
"LEFT TANK"	If needed talks gunner into target area	Traverses turret and announces "IDENTIFIED"	Ensures path of recoil is clear and safety switch is on "FIRE" Announces "UP"	Prepares to sense rounds.
"FIRE"	Assumes position to sense round to be fired	Aims at base of target, announces "ON THE WAY" and fires	Prepares to load next round and braces	
"TARGET" RIGHT TANK	If needed talks gunner into target area	Traverses turret and announces "IDENTIFIED"	Loads second round announces "UP"	
"FIRE"	Assumes position to sense round to be fired	Aims at second target, announces "ON THE WAY" and fires. After firing the gunner continues the engagement and applies burst on target if required.	Prepares to load next round and braces	

The tank commander observes the red flash as the round strikes the enemy tank and he announces "TARGET":

Fourth Engagement:

The tank commander surveys the area to his front with his binoculars and orders the driver to "MOVE OUT." The tank moves out at about 10 miles per hour down the forward slope of the ridge. The turret is in the stabilized mode; all crewmen are observing for potential enemy targets. The tank commander observes what appears to be about eight enemy soldiers deployed as skirmishers in a field to the right front at an estimated range of about 700 meters. The enemy appears to present an area target. The following actions take place:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER COAX"	Lays gun for direction	Ensures appropriate switches are still on	Checks the coax machine gun visually to ensure safety is in "fire" position	Continues to move forward, attempts to orient hull toward the target
"TROOPS"	If needed talks gunner into target area	Ensures that ammunition is indexed and and checks firing switch	Prepares to observe functioning of COAX in event of stoppage and announces "UP"	Continues tank movement at a smooth rate.
"RIGHT FRONT"	Estimates range	Traverses turret in search of target & announces "IDENTIFIED"		
"SIX HUNDRED"		Lays gun for range and deflection. Takes correct sight picture with infinity sight and announces "ON THE WAY"		
"FIRE"	Prepares to observe strike of rounds	Fires "Z" pattern on the area target of enemy troops		
"CEASE FIRE"				

The gunner when using the "Z" pattern will open fire on the near edge of the target and let the movement of the tank walk the burst across the width of the target forming the bottom of the "Z". He then traverses the burst back across the target to the far edge using turret movement. This forms the middle bar of the "Z." Finally, he uses the movement of the tank to walk the burst again across the side of the target completing the "Z" pattern.

Fifth Engagement:

The driver continues to move the tank along at the same rate of speed while selecting the most covered route of advance. As the tank reaches the bottom of the hill and starts up the slope, the commander observes what appears to be an enemy anti-tank gun camouflaged on the forward slope of the ridge his direct front at a range of approximately 1,600 meters. The tank commander believes that his position has been undetected by the enemy. He decides to engage the enemy anti-tank gun with HEP ammunition and precision technique from a covered position. He directs the driver to a hull defilade position. Since the tank commander decided on the above type of engagement, the following method will be used. The tank commander will determine range utilizing the rangefinder. The gunner will use the telescope with the HEP reticle. The gunner will receive range information either as an element of the fire command from the tank commander (the most common method) or he may receive his range from the "read out" of the computer. The following actions are taken by the tank crew:

Fire Command Element	Tank Commander	Gunner	Loader	Driver
"GUNNER HEP"	Lays gun for direction	Ensures appropriate switches are on. Moves over to the telescope and moves selection lever to HEP reticle	Loads HEP round. Checks to ensure turret ring is clear	Selects defilade firing position
"ANTI TANK"	If needed, talks gunner into target area	Indexes ammunition into computer and selects firing switch	Ensures path of recoil is clear and safety switch is in "FIRE" position. Announces "UP"	Stops tank smoothly
"DIRECT FRONT"	Ranges to target	Traverses turret & announces "IDENTIFIED"	Prepares to load next round.	Locks brake, braces, and prepares to sense round.
"ONE SIX HUNDRED"	Assumes position to sense round	Takes correct sight picture aiming on center of target, & announces "ON THE WAY"	Braces	
"FIRE"		Fires		

The round is observed striking the ground and throwing up dirt, just short of the anti-tank gun. The crew reacts as follows:

SENSING	TANK COMMANDER	GUNNER	LOADER	DRIVER
"SHORT ADD TWO HUNDRED FIRE"	Announces sensing correction and prepares to sense	Makes range correction in sight picture, announces "ON THE WAY" and fires	Loads HEP round. Ensures safety switch is on "fire". Announces "UP"	Prepares to sense subsequent round, or move out.

The tank commander observes the flash as the round strikes the enemy anti-tank gun and announces "TARGET CEASE FIRE" Upon completion of the engagement, the tank commander directs the driver to "move out" in order to continue the attack. As tank 23 moves out, the tank commander monitors a transmission over the platoon net advising the platoon to be alert for enemy air activity. Enemy helicopters, both observation and gun ships have been reported in the area of operation. It is late in the day and dusk is beginning to settle in. The tank commander is searching the sky through his binoculars. With darkness descending, the gunner is now utilizing the tank thermal sight (TTS). The tank commander can view the same target area that the gunner sees by use of his tank thermal sight. As the tank continues to climb the slope, the commander hears the rotor blades of a helicopter. At that time, he hears what seems to be an enemy attack helicopter attacking the left flank tank of his platoon. This is immediately confirmed by a report of the platoon radio net.

Sixth Engagement:

The commander of tank 23 takes immediate action to engage the enemy helicopter. Since it has turned dark, the image intensification sight has been installed in the tank commander's cupola for firing the M85.50 caliber machine gun. It is with this system that the enemy helicopter is engaged. The tank commander alerts the crew by announcing "CALIBER 50." After locating the enemy helicopter in his image intensification sight, the tank commander engages it. He detects the helicopter moving toward him with no apparent speed. He therefore aims high. He fires at a high rate of fire and engages the helicopter with a continuous burst, adjusting onto target by observing tracers. The driver continues the tank's movement forward and is prepared to take evasive action if the tank is threatened. If the enemy helicopter is hovering, it is an indication that it is

preparing to fire an ATGM. When the tank commander observes the helicopter destroyed, he announces "END OF MISSION."

As the tank platoon approaches the crest of the next ridge, the tank commander of tank 23 receives word over the platoon net that the unit will halt for the night in this general area. Mechanized infantry will soon join the tanks and provide local security during the night. The tank commander is assigned a sector of responsibility for the organization of the defensive position. The tank commander directs the driver to position the tank in a primary position for the night. He also points out to the gunner, some possible avenues of enemy approach so that the gunner may begin to prepare a range card for possible night firing from the position. The tank commander accompanies the platoon leader on a reconnaissance of the area in order to select alternate and supplementary positions, and plan defensive fires. The gunner, assisted by the loader, performs necessary turret maintenance on the tank and replaces ammunition in the tank, which was expended during the day. When this has been accomplished, they (gunner and loader) work on the preparation of a range card, in the absence of the tank commander. The driver performs after-operations maintenance on the automotive system of the tank and supervises the refueling of the tank.

The tank commander returns from his reconnaissance and informs the crew that the enemy is believed to be nearby and that engagement of enemy targets at night is probable. He further informs the gunner that the principal threat is enemy armor and that the crew will prepare for a possible "battlesight" engagement using HEAT ammunition. HEAT ammunition is therefore loaded in the main gun and is indexed. The crew is further instructed by the tank commander that every attempt will be made to maintain the secrecy of their position. If it becomes necessary to engage the enemy at night, the following priorities are established for firing modes: First, the use of the tank thermal sight (TTS), which will maintain night vision and will provide for complete surprise in the initial engagement. This will deny the enemy any obvious source of light by our tanks. Second priority, the use of indirect illumination by mortar shells from the mortar platoon. Third priority, infrared mode by out tank mounted searchlights; and last priority, white light from the searchlight . The infrared light provides the possibility of detection by the enemy, and the source of white light provides an excellent target for the enemy. The crew is cautioned about the use of visible illumination at night. When the gunner announces "ON THE WAY," the entire crew must close or cover their eyes before the main gun flash, in order to preserve their night vision. When using visible illumination at night, the tank commander uses only one eye to acquire targets and sense rounds so that night vision can be retained by the other eye.

Shortly after dark, a tank on the left flank of the battalion detects and successfully engages an enemy tank utilizing the tank thermal sight. The tank thermal sight (TTS) permits near daylight tactical operations under conditions of limited visibility. Thermal imaging is independent of ambient light because it senses heat emitted by a target and forms an image on the screen. The TTS has an elbow which allows the commander to view the same scene as the gunner, thus enabling the commander to fire the main gun independently during periods of limited visibility.

Seventh Engagement:

Shortly after dark, the tank commander, while monitoring the tank thermal sight, detects an enemy tank which has moved into view to his direct front at an estimated range of 1,000 meters. The following actions take place:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER BATTLESIGHT TANK"	Lays gun for direction	Ensures turret power is on	Checks the turret ring and ensures turret is not locked	Prepares to sense round with one eye after flash
"DIRECT FRONT"	If needed, talks gunner into target	Announces "IDENTIFIED" and makes final lay of the gun	Ensures path of recoil is clear. Places safety switch in "FIRE" position, announces "UP"	
"FIRE"	Cover eyes and prepares to sense round after flash	Aims at base of target, announces "ON THE WAY" covers eyes and fires	Prepares to load next round, braces	

The tank commander and crew all cover their eyes when they hear "ON THE WAY." After hearing the bang, the tank commander uncovers one eye in order to sense the round. He observes the round as it passes slightly over the top of the enemy tank. The following actions take place:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"OVER DROP TWO HUNDRED"	Announces sensing correction and prepares to sense, but covers eyes first	Makes range correction in the sight picture announces "ON THE WAY", covers eyes	Makes sure safety switch is on "FIRE" and announces "UP"	Covers eyes

The tank commander, with one eye open, observes the red flash as the enemy tank is hit. Although no other targets appear at this time in the section of tank 23, enemy activity seems to be picking up along the entire defensive position. Adjacent units have begun engaging the enemy, utilizing flares for illumination.

The gunner surveys the area with his tank thermal sight and the tank commander monitors this through his periscope. In addition, if sufficient ambient light is available, the tank commander may search the area with the image intensification sight on his M85.50 caliber machine gun. The tank commander notices considerable enemy activity with many dismounted troops appearing at an estimated range of 1,200 meters in the valley below. Inasmuch as there are many friendly flares being fired over the valley, the tank commander decides to engage the enemy troops to his front with the .50 caliber machine gun, utilizing daylight firing techniques.

Eighth Engagement:

After estimating the range to the target, the tank commander alerts the crew by announcing "CALIBER 50." He utilizes the ballisitc reticle to ensure the first burst is in the target area. He uses the low rate of fire, firing bursts of 10-15 rounds, using 2 - 3 tracers. He uses the "Z" pattern,opening fire on the near edge of the target and walks the burst across the width of the target forming the bottom of the "Z." Then traverses the burst back across the target to the far edge. This forms the middle bar of the "Z." He finally walks the burst again across the far side of the target, completing the

"Z" pattern. He adjusts for elevation, using the manual elevation handle and adjusts for deflection using the TC override. The tank commander observes the target area and announces "END OF MISSION" after firing about 50 rounds. While the tank commander has been involved in acquiring and engaging an enemy troop target with the .50 caliber machine gun, the gunner has noticed an enemy tank in the valley below which has opened fire on elements of the right flank. The gunner acquires the target in his tank thermal sight and informs the tank commander. The tank commander identifies the target and decides to engage it.

Ninth Engagement:

The following actions will be taken by the tank crew:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER SABOT"	Lays gun for direction if required	Ensures appropriate switches are on	Ensures turret ring is clear, loads gun	Prepares to sense round with one eye after flash
"TANK"		Looks through sight and lays for deflection	Ensures path of recoil is clear and that safety switch is on "FIRE"	
"DIRECT FRONT"	Ranges to target	Announces "IDENTIFIED"	Prepares to load next round	Covers eyes
"ONE EIGHT HUNDRED"		Takes correct sight picture announces "ON THE WAY"	Braces	
"FIRE"	Assumes position to sense round	Fires		

The tank commander observes the bright red flash as the round strikes the enemy tank and he announces "TARGET". If the round had missed the target, the gunner should have sensed the round and immediately applied "burst on target" (B.O.T.).

10th Engagement

Shortly after successfully engaging the enemy tank by flare illumination, the tank commander received a transmission over the platoon net informing him that a friendly unit on the right flank was under heavy attack by the enemy. The platoon has been ordered to move to their supplementary position in order to better defend the battalion sector of responsibility.

As tank 23 approaches the supplementary position,the tank commander observes what he believes to be enemy troops approaching the tank from the left, through the darkness,at a range of approximately 100 meters. He immediately issues the following fire command "LOADER - MACHINE GUN - TROOPS - LEFT FLANK - ONE HUNDRED - FIRE". The loader immediately mans his machine gun and commences to fire suppressive fires into the left flank area. He fires bursts of 10-15 rounds every 10 seconds for approximately 60 seconds at which time the tank commander announces "CEASE FIRE".

11th Engagement

On the following morning,shortly after daylight, the tank battalion is ordered to resume the attack. Tank 23 of the second platoon leads the platoon across the line of departure in a wedge formation. All crew members are scanning the area to their front in search of potential targets. At that moment an enemy attack helicopter pops up above the ridge line to the front. The helicopter hovers for a few seconds and then fires an ATGM. Fortunately the missile passes over the top of tank 23. The following actions are taken by the crew of tank 23.

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"CALIBER 50"	Looks through commander's sight	Observes for additional enemy aircraft	Prepares to assist TC if necessary	Makes sharp turn to right or left in order to evade enemy

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"CHOPPER"	Aims above the heli-copter if it is still hovering.			Keep crew alerted to any sudden change in direction.
"DIRECT FRONT"	Fires burst of 10-15 rounds at high rate of fire until air-craft is destroyed.			

Upon observing the destruction of the enemy helicopter, the commander announces "END OF MISSION" and immediately alerts other tanks in the area that an enemy helicopter with an ATGM was in the area. Attack helicopters usually travel in teams of 2. Tank 23 continues forward and over the next ridge line onto an open field. At this point, the tank commander observes what appears to be about ten dismounted enemy troops to his right front at an estimated range of 1,500 meters. He is about to engage the enemy with his .50 caliber machine gun when he notices what appears to be an enemy tank in hull defilade to the left front at an estimated range of 1,900 meters. The tank commander has decided to engage both targets but recognizes that the enemy tank is the greater threat and must be engaged first from the short halt. The commander orders the driver to halt.

Twelfth and Thirteenth Engagement:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER SABOT"	Lays gun for direction	Ensure appropriate switches are on.	Checks to insure turret ring is clear. Loads ADPS.	Selects defilade firing position.
"TANK"		Indexes ammunition into computer and selects firing switch.	Ensures path of recoil is clear, places safety switch on "FIRE" and announces "UP".	Stops tank smoothly upon command.
"LEFT FRONT"	If needed talks gunner into target area and ranges on target	Traverses turret in search of target and announces "IDENTIFIED"	Prepares to load next round if required	Locks brakes, braces, and prepares to sense the round.
"ONE NINE HUNDRED"		Makes final lay of gun for deflection and announced range	Braces	
"FIRE AND ADJUST"	Prepares to engage enemy troops with Cal 50	Fires, senses, and completes engagement without assistance from the TC		

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"CALIBER 50"	Looks through commander's sight.	Announces "TARGET-CEASE FIRE" (indicating main gun engagement is ended)		
"TROOPS ONE FIVE HUNDRED"	Estimate range and uses ballistic reticle, fires at low rate bursts of 10-15 rounds using manual elevation handle and TC override as gunner is finished with main gun engagement		Prepares to assist TC if necessary	
"END OF MISSION"	Ceases fire.			

The driver is ordered to "MOVE OUT" and tank 23 continues the attack. The tank commander realizes that additional enemy tanks may be in the area and he therefore instructs his crew to be prepared for a possible HEAT battlesight engagement. HEAT ammunition is therefore loaded and indexed.

Fourteenth Engagement:

As the tank moves over the crest of the next hill, there is a loud crack and an explosion causes dirt to be blown up about twenty-five yards in front of the tank. The loader points to what appears to be an enemy tank to the right front at an estimated range of about 800 meters. The tank commander believes that that was the tank that just fired on him and missed. The crew reacts immediately as follows:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER BATTLE-SIGHT"	Lays gun for direction	Ensures turret power is on	Checks the turret ring and ensures it is clear	Continues to move forward attempts to orient hull
"TANK"		Looks through periscope and turns to final target	Ensures path of recoil is clear and that safety switch is on "FIRE"	Prepares to sense round
"RIGHT FRONT"	If needed talks gunner into target area	Traverses turret in search of target and announces "IDENTIFIED"	Announces "UP" and is prepared to load another round	
"FIRE"	Assumes position to sense round to be fired	Aims at base of target announces "ON THE WAY"	Braces	

The tank commander observes the red flash as the round strikes the enemy tank and he announces "CEASE FIRE" and tank 23 continues in the attack.

Fifteenth Engagement:

Tank 23 moves forward as the lead tank in the platoon wedge formation. The tank commander notices a large knoll of ground which is heavily wooded. He realizes that the other tank section on his left will bypass this high ground thus exposing his left flank. He decides therefore to take this area under fire with suppressive fires as a suspected troop target. The crew reacts as follows:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER COAX"	Lays gun for direction	Ensures appropriate switches are still on	Checks the COAX gun visually to ensure safety is in "FIRE" position	Continues to move forward attempts to orient hull toward the target
"TROOPS"	If needed talks gunner into target area	Ensures that ammunition is indexed and checks firing switch	Prepares to observe functioning of COAX in the event of stoppage.	Continues tank movement at a smooth rate.
"LEFT FLANK"	Estimates range	Traverses turret in search of target and announces "IDENTIFIED"	Announces "UP"	
"FIVE HUNDRED"		Lays gun for range and deflection. Takes correct sight picture with infinity sight and announces "ON THE WAY"		
"FIRE"	Prepares to observe strike of rounds.	Fires burst of 10-15 rounds every 10 seconds for approximately one minute		
"CEASE FIRE"				

Sixteenth Engagement:

It is now about dusk and darkness is closing in. A transmission has been received notifying the platoon the attack is going very well. Since the enemy appears to be somewhat disorganized,it has been decided to continue the attack. After a brief halt for refueling and replenishment of expended ammunition the battalion continues in the attack. Tank thermal sights (TTS) and other night vision devices have been installed. The tank commander of tank 23 recognizes that some enemy tanks are still capable of providing a threat. He has instructed his crew to be prepared for a battlesight engagement utilizing HEAT ammunition. The main gun is loaded and the ammunition is indexed. As the tank moves over the crest of a ridge,the tank commander and gunner are searching the area to their front with thermal imaging sights. The tank commander observes what appears to be an enemy tank to his left front at an estimated range of 800 meters. The following actions are taken by tank 23.

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER BATTLE-SIGHT"	Lays gun for direction	Ensures turret power is on	Checks the turret ring and ensures it is clear	Continues to move forward and attempts to orient hull
"TANK"		Looks through tank thermal sight and tries to find target	Ensures path of recoil is clear and that safety switch is on "FIRE"	Prepares to sense round
"LEFT FRONT"	If needed talks gunner into target area	Traverses turret in search of target and announces "IDENTIFIED"	Announces "UP" is prepared to load another round and braces.	Continues to drive forward and is prepared to momentarily cover his eyes.
"FIRE"	Assumes position to sense round after momentarily covering his eyes.	Aims at base of target and announces "ON THE WAY"		Momentarily covers eyes.

The tank commander observes the round strike the tank and he and he announces "CEASE FIRE".

Seventeenth Engagement:

As tank 23 continues to advance, the gunner observes an enemy truck on the right flank which appears to be carrying troops. He points out this potential target to the tank commander. The tank commander reacts as follows:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER COAX"	Lays gun for direction using commander's tank thermal sight	Looks through thermal sight of the gunners periscope	Checks the COAX gun visually and ensure safety switch is on "FIRE"	Continues to move forward attempts to orient hull toward the target
"MOVING TRUCK"	If needed talks gunner into target area	Ensure ammunition is indexed and checks firing switch	Prepares to observe functioning of COAX in event of stoppage and announces "UP"	Continues tank movement at a smooth rate.
"RIGHT FLANK"	Estimates range	Lays gun for range and deflection. Takes 5 mil lead.		
"SEVEN HUNDRED"		With infinity sight and announces "ON THE WAY"		
"FIRE"	Prepare to observe strike of round	Fire, observes strike and makes necessary adjustment		
"CEASE FIRE"				

As the tank continues on the gunner and tank commander scan the area to their front. The countryside is quite flat and has little vegetation. The tank commander believes that any targets in this area will be taken under fire at mid-ranges or greater. He therefore directs the gunner and loader to prepare for a battlesight engagement with ADPS ammunition. The ammunition is loaded and indexed as directed.

Eighteenth Engagement:

The tank commander, through his tank thermal sight, has observed two enemy tanks. One tank to the direct front is moving directly toward the attack at an estimated range of 1,300 meters, the other enemy tank is moving from left to right at a greater range of approximately 1,500 meters. The tank crew reacts as follows:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER BATTLESIGHT"	Lays gun for direction	Ensures appropriate switches are on and looks through thermal sight	Checks to see that the turret ring is clear	Continue to move forward attempts to orient hull
"LEFT TANK"	If needed talks gunner into target	Traverses turret and announces "IDENTIFIED"	Ensure record is clear and safety switch is on "FIRE" Announces "UP"	Prepares to temporarily cover eyes.
"FIRE"	Covers one eye and prepares to sense round	Aims at base of target announces "ON THE WAY" and fires	Prepares to load next round, and braces	
"TARGET MOVING TANK RIGHT FRONT"	If needed talks gunner into target area	Traverses turret and announces "IDENTIFIED"	Loads second round announces "UP"	
"FIRE"	Covers one eye and prepares to sense round	Aims at second target, announces "ON THE WAY" fires, applies "Burst on Target" if required.	Prepares to load next round and braces.	

Nineteenth Engagement:

As tank 23 starts up a long hill, about 20 dismounted enemy troops are observed skyline on the ridge to the left front. The tank commander takes the following action:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER COAX"	Lays gun for direction	Ensures appropriate switches are still on	Checks COAX machine gun visually to ensure safety is in "FIRE" position	Continues to move forward, attempts to orient hull toward the target
"TROOPS"	If needed talks gunner into target area	Ensures that ammunition is indexed and checks firing switch	Prepares to observe functioning of COAX in the event of a stoppage and announces "UP"	Continues tank movement at a smooth rate
"LEFT FRONT"	Estimates range	Lays gun using thermal sight and announces "IDENTIFIED"		
"SIX HUNDRED"		Takes correct sight picture with infinity sight and announces "ON THE WAY"		
"FIRE"	Prepares to observe strike of rounds	Fires "Z" pattern on the area target of the enemy		
"CEASE FIRE"				

Twentieth Engagement:

The attack continues and as the tanks move across the open ground,the area to the immediate front is being illuminated by the employment of illuminating shells fired by the mortar platoon of the tank battalion. As long as the target area is illuminated by this method, enemy targets can be engaged utilizing daylight firing techniques. Through this illumination, the tank commander observes what appears to be an enemy anti-tank gun at an estimated range of 1,500 meters. He has decided to engage this type of target with HEP ammunition. Since the range is greater than 1200 meters,the drift of HEP ammunition will not permit the gunner to use his periscope. He must therefore use the secondary sight which is the telescope with its ballistic reticle for HEP ammunition. The tank crew will conduct a precision engagement from the halt. The commander orders the driver to halt. The crew takes the following actions.

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"GUNNER HEP"	Lays gun for direction	Ensures appropriate switches are on. Moves over to the telescope and moves selector lever to the HEP reticle	Loads HEP round checks to ensure turret ring is clear	Selects defilade firing position.
"ANTI-TANK"	If needed talks gunner into target area	Indexes HEP ammunition into the computer and selects firing switch	Ensures path of recoil is clear and safety switch is in "FIRE" position	Stops tank smoothly
"DIRECT FRONT"	Ranges to target	Traverses turret and announces "IDENTIFIED"	Announces "UP", prepares to load next round	Locks brakes braces and prepares to sense the round
"ONE FIVE HUNDRED"	Assumes position to sense round	Takes correct sight picture announces "ON THE WAY"	Braces	
"FIRE"		Fires		

The tank commander observes the round passing over the top of the anti-tank gun and striking the ground on the hillside beyond. The crew reacts as follows:

FIRE COMMAND ELEMENT	TANK COMMANDER	GUNNER	LOADER	DRIVER
"OVER DROP TWO HUNDRED"	Announces sensing correction and prepares to sense subsequent round	Makes range correction in sight picture announces "ON THE WAY" and fires	Loads HEP round, ensures safety switch is on "FIRE" position and announces "UP"	Prepares to sense subsequent round or move out
"TARGET CEASE FIRE"				

5.3 Overall Mission Training Requirements

The M60A3 crew is responsible, as a whole, for six functions in the tactical employment of the tank. Each function involves individual tasks and procedures, but none is perfomed on an individual basis. The efficiency of the entire crew depends on the quality of crew coordination taking place as each function is performed.

5.3.1 Terrain Appreciation. Every mission requires that the crew thoroughly analyze the terrain over which the mission will take place. Each crewman is involved in this analysis as he performs his part of the crew's job. Normally, the tank commander is responsible for analyzing the terrain for its tactical implications, but each member of the crew interacts with the terrain in one way or another, and he must also become familiar with its effects on his performance.

Terrain appreciation requires practice and experience in moving about the terrain, and in observing other elements as the terrain is used to the best advantage. Good training in terrain appreciation is available in motion pictures and in terrain study, both in the real world and through the use of terrain boards and sand tables. Very little training is available for integration of crew terrain appreciation skills in a context of real-world missions and engagements. Crews have little or no opportunity to make predications which are confirmed or rejected in dynamic settings where the consequences of each crew response directly influence the outcome of the crew's tactical performance. Good training is available in the basic skills, but not in the timely application and refinement of those skills.

5.3.2 Route Selection. The tank commander and the driver select the route to be taken by the tank as it moves toward its objective. As available maps, charts and photographs, intelligence and combat reports, and direct viewing of the terrain from the tank or from a helicopter or other vehicle are all employed, in selecting the route providing the best speed, coordination with adjacent elements, cover, concealment and access to the objective and to threats expected along the way. The degree of tank commander involvement in route selection is to some extent proportional to the training and experience level of the driver. In most cases, the tank commander's perception of the tactical situation is more complete than that of the driver, particularly as it involves information about the deployment and roles of adjacent and supporting elements, and the deployment of threats within the battle area. As the tank enters its mission phase, the responsibility for route selection shifts to the driver, who attempts to emphasize speed, coordination with other elements, maneuverability, security and the visibility of the battlefield from the turret. The tank commander still provides guidance, but the kind and amount of guidance depends on the situation, the driver's experience and skill, and the tank commander's workload. The loader and the

gunner also participate in the selection of the route. The gunner has magnified optics available to help him to evaluate obstacles and possible threat areas, while the loader, when traveling head-up, has a panoramic view similar to that of the commander.

Each member of the crew involved in route selection evaluates available routes in terms of their probable effects on the mobility of the tank and on its vulnerability to observation and engagement. Obstacles, possible fields of fire, terrain surfaces, and sources of cover and concealment are studied in detail by each member of the crew, from his own unique vantage point, to determine the best way to move in a usually, rapidly changing situation.

Training in route selection is limited by the availability of terrain, partly because of the effects of tank travel on tactical driving areas, and partly by the types of terrain the tank can negotiate. Each member of the crew must be aware of how the tank will react to various obstacles, surfaces, and slopes. The driver in particular, must also be able to visualize the appearance of the tank from the areas of potential threat through which it must move. This is also difficult for him to learn, again due to the limited availability of useful training areas.

5.3.3 Route Negotiation. The crew negotiates the terrain by continuously evaluating the response and the exposure of the tank as it moves about. Since ideal routes are rarely available, the crew is usually forced to select the best of a number of choices (none of which may be desirable) while maximizing speed, agility, cover, concealment, or firing position - depending on which are the most important at a given time.

Although the M60A3 can safely negotiate a variety of terrain surfaces and obstacles, each surface has its effect on speed, maneuverability, and on the life of the tank itself. Drivers must have experience driving over as many types of terrain as possible to determine those which it can negotiate and those which it cannot. In actual field training, it is difficult for the driver to be exposed to a variety of surfaces. It is also not feasible for him to practice on marginal terrain for reasons of safety, impact on the terrain, and because of the extreme forces which would be placed on the track, suspension system, and on other parts of the tank. As a result, even drivers assigned to tactical units do not have adequate opportunities for developing the "feel" required for safe and effective tactical driving. Tactical driving requires that the driver be able to predict, without trial and error, the effects of a surface or an obstacle on his tank so that he can exercise the right kind of control in negotiating all of the types of terrain and surface conditions he would encounter in actual combat. Needless to say, the combat tank driver who must feel his way along a route, or who picks the obviously

more negotiable route will expose his tank to fire more often and for longer periods of time than the driver who knows from experience how his tank will react to each kind of surface and condition.

5.3.4 Target Acquisition. Target detection, recognition and acquisition are, like terrain appreciation, highly complex skills which require a great deal of field training, in real terrain, in real visibility and weather conditions, with targets approximating those the crew will observe on the armor battlefield. Skill in target acquisition increases the range at which tanks can be detected, evaluated, evaded or engaged and thus tends to minimize the vulnerability of the tank and to determine its ultimate effectiveness. Target acquisition requires that once something of interest is detected, it be recognized and evaluated. Frequently, the tactical situation is so well known that anything detected can be considered hostile, and it may be assumed to be one of a very few types. In other cases, of course, the crew must be able to discriminate between hostile and friendly elements and among various types of threat. The M60A3 has three types of weapons, with several types of ammunition. Threatening elements, defined as targets, must be engaged with the weapons and the ammunition appropriate to the threat type, range, and tactical situation at the time. Use of the wrong ammunition could alert the threat and bring return fire on the tank before the tank is able to neutralize it. In addition, targets must be discriminated so that a priority for engagements or evasion may be assigned. When the crew is faced with more than one threat, the most lethal should usually be engaged first. Even when only one target is detected, the crew must decide whether to engage it or not. If the threat has not detected the tank, it may be best to track it until the range is reduced, the threat moves out of the area, or until the threat's supporting elements are detected.

Target discrimination is based partly on the shape of its visual image, but frequently it must be based on a combination of the image and signs of activity. In some cases, even in daylight, the IR image of a concealed or partly-concealed threat in the thermal sight can be used to identify the threat. Weapon effects can also provide useful information about what the threat is, and its significance to the tank.

Finally, once a target has been detected, recognized, and assigned a priority, if it is to be engaged, it must be acquired in the weapon sighting system. When the gunner fires the main gun or the coaxial machine gun, he must acquire the target in his periscope, unity power window, or in the gunner's periscope. Since each of these has a very narrow field of view, the tank commander identifies the target type, its approximate range and, when necessary, some pertinent feature near it. The gunner searches in his sights while the tank

commander slews in the vicinity of the target. When it enters his field of view, he identifies it and lays the appropriate reticle or reticle element on the tank in preparation for firing.

Current training in target detection and acquisition presents information to the tank crews about the images and signs of threat, United States and NATO vehicles and equipment. Motion pictures, silhouettes and in some cases, real threat vehicles operating within threat tactical doctrine are used for training crews in detection and recognition. Opportunities for detecting, providing,and engaging targets under fire conditions are rare, although REALTRAIN exercises have been extremely effective. The varieties and amount of terrain needed for real-world training are prohibitive, but systematic training has been successful in training crews to recgonize and discriminate most of the targets they would encounter in combat.

5.3.5 Target Engagement.

When a target has been acquired and recognized, the tank commaner, or any other crewmember who recognizes it first, alerts the crew to its type and location. When two or more targets are detected, the tank commander decides which to engage first by evaluating the potential of each target as an immediate threat and also by evaluating the means available to the tank for the engagement of targets. The most lethal target is attacked first; if it is a tank or other land target, it is engaged with the main gun, by the gunner; the tank commander may choose to engage from his own position, depending on the circumstances, leaving the gunner to fire suppressive fire with the coaxial machine gun, or to search the immediate area for other threats.

In some cases, where more than one target is presented, the tank commander may engage one target with the .50 caliber while the gunner employs another with the main gun or the coaxial. During all engagements, the entire crew attempts to observe the effects of firing so that the engagements may be continued or terminated as appropriate. The loader, of course, has little contact with the target and during main gun or coaxial engagements, also does a minimum of sensing.

During all engagements, the driver places the tank in the most advantageous position for the circumstances at hand. Theoretically, he waits for a command from the tank commander, but depending on the urgency of the situation and on the amount of information available to him, he may choose on his own, or hide the tank, hide the hull and expose the turret, stop in a firing position, accelerate or slow down. The gunner may also choose to act on his own; he may alert the crew and engage an especially lethal target simultaneously. The primary function of the crew is to engage quickly and accurately, and to survive on the battlefield. Crew and crew

interaction training is directed at these objectives. Current training in crew interaction is unable to provide practice in tactical crew interaction because of limitations in terrain and interactive targets, although REALTRAIN exercises have been extremely effective in alleviating this problem, within severe terrain constraints.

5.3.6 Tactical Decision Making. Each member of the crew participates in the process of deciding what to do next. Decision-making and tactics are primary responsibilities of the tank commander, but the driver and to a lesser extent, the loader and the gunner contribute to the decision-making process. Tactical information comes to the crew in at least three different ways. Each mission is preceded , in one way or another, by a briefing with maps, photos and intelligence information about the mission, the threat, the terrain and the friendly support elements. Usually, the commander attends the briefing and subsequently provides the crew with as much information as they can use. Tactical information is also provided through radio communications, primarily during the mission. Security limits the amount of information furnished over the radio, but a great deal of information is provided in this way. Also, as the mission progresses, everything of interest observed by a crew member is shared with the entire crew, so that each event fits into each crew member's perception of the situation, improving his ability to respond quickly and realistically.

5.4 Crew Training Requirements

The crew of the M60A3 receives effectine training in the operation and maintenance of the tank and its systems. Training at both the Armor Center an at field units to which the crews are assigned following AIT (now BAT) training, is given in standardized, well-controlled settings. Safety, cost, and facilities considerations limit the amount of interactive training and also limit interactive training in tactical settings. The effect of tactical interaction on crew skills is profound, both in terms of the stresses that accompany armored combat and in the ability of the crew to respond to similar, but essentially different task conditions.

M60A3 crews interact largely on the basis of visual information about the terrain, the threat and the performance of the tank and its systems. The terrain and the threat produce a great deal of information, all of which requires skilled analysis on the part of the crew. The terrain includes the features which can conceal or protect the tank from observation and fire, obstacles to be negotiated and that may degrade the movement of the tank and also the threat.

The threat can take any of a large number of forms, and it can appear or otherwise reveal itself in combinations, each of which has specific meaning for the crew. Both the terrain and the threat have important implications for the training of each member of the crew, and for the training of the crew in working

as an integrated, articulated team.

5.4.1 Tank Commander. The tank commander guides the movement of the tank, detects targets,and organizes the response of the entire crew to the situations arising out of the tank's mission in engaging and destroying threats. The tank commander also maintains visual and radio contact with other friendly elements supporting his tank's mission, and with elements being supported by his unit. In effect, the tank commander is responsible, and is the operator of a complex, highly versatile weapon system, assisted by a crew of specialists who operate the fire control, weapon and automotive systems. The tank commander is chosen for his job on the basis of training, experience, and leadership ability. Usually the tank commander has at one time or another served in each of the other three crew positions; at the very least, he is qualified to perform the driver's, gunner's, and loader's tasks.

The tank commander is not only a weapon system commander, but is also a tactician: he operates the tank, but equally important, he employs the tank in specific tactical settings, responding to the demands of each situation for maximum mission effect and maximum security. In addition, of course, the tank commander is the crew's instructor. One of his primary responsibilities is to meet the training schedule prescribed for M60A3 crews, and to expose the crew to situations and exercises designed to develop and maintain their proficiency for tank combat. Although tank commanders, typically, have had one or more tours of duty in combat-ready tank units, they, like the crews they supervise, have little or not experience in the kinds of tactical exercises in which tanks are expected to be employed in the future. Tables VIII and IX, and a variety of field exercises have been and are being used to good effect, in developing individual and crew tactical skills. Current training exercises are constrained by terrain, fuel,ammunition, facilities and personnel limitations, and are necessarily stylized and artificial. As a result, they neglect many training objectives relating to combat crew skill.

The tank commander is responsible for the tactical employment of the tank in combat, within its assigned mission and its support setting. The tank commander performs many functions in fulfilling this responsibility, each of which involves a number of decisions and actions which influence the entire crew and the tank's mission.

5.4.1.1 Analyze Terrain. Effective analysis of the terrain requires that the tank commander understand the principles of employment governing his own operations and those governing the threat anticipated in the battle area. He must also understand the characteristics of his tank, and of the threat, as they move through the terrain, so that he can anticipate the areas in which the threat might and might not appear, and those

in which he may or may not be able to move. In addition, he must know the effects of the terrain on his ability to move. Some surfaces will stop the tank, while others will only slow it. He must also be able to anticipate terrain areas which would logically be mined or sighted in by friendly or hostile fire support.

Much of the training required by the tank commander in terrain analysis and appreciation can be provided in classroom settings, but the ability to react realistically and quickly to terrain characteristics on the battlefields, requires experience in maneuvering the tank on the battlefield, in a hostile environment.

5.4.1.2 Control of the Tank in Formation. The M60A3 always operates with other tanks. The tank as a unit of a formation has at least one tank at each side, and even the tank operating on the flank of the formation has at least one friendly tank in its field of view. In a bounding overwatch, each tank sees the maneuvering tank to its front at least part of the time. Since tanks provide mutual support for each other, it is essential that the commander of each tank maintain the proper position with respect to other tanks in the force at all times.

Control of relative position between two tanks is a difficult task in a tactical situation. The commander controls the tank through commands and guidance to the driver, but his direction to the driver must be consistent not only with the position of other freiendly elements, but with the overall objective of the mission and with requirements for security as well. The tank commander must select a route which can support and conceal his own tank, which is not too far from the route available to the adjacent element,and which contains firing positions which are capable of interlacing with those available to the adjacent tank. He must also choose a route which leaves room for both elements to maneuver if and when threats are encountered. Again, opportunities for learning to control the tank in a tactical position are almost nonexistent; those opportunities which are available are highly stylized, and rarely involves significant interactions with the terrain, with the threat, and among supporting elements.

5.4.1.3 Weapon System Operation. The tank commander's sighting, ranging and fire control equipment gives him control over all of the weapon systems in the tank, with the exception of the loader's machine gun. His position in the turret also gives him the best visual contact with the battlefield environment and with the enemy elements making up the threat. Ordinarily, the tank commander directs the gunner to engage targets, using the main and coax gun, but in some situations,the tank commander may use one of the weapons to supplement that (weapon) being used by the gunner or to reduce the time required to fire the first round or burst of machine gun fire.

When the gunner has a close-range main gun target, and when troops or lightly-armored vehicles in the same area pose a threat, the tank commander may fire the coaxial machine gun to suppress activity by the troops or by the supporting vehicles, especially when they may be launching ATGM's.

The tank commander also has his own .50 caliber machine gun in the cupola and he can use this to attack lightly-armored vehicles and troops. Tank commanders are almost always experienced gunners who have qualified on each of the tank's weapons. Like the rest of the crew, they need better training in the employment of these weapons in complex tactical situations.

5.4.1.4 Machine Gun Employment. The coax gun and the .50 caliber are intended primarily to attack and destroy area targets, lightly armored vehicles, troops,and low-flying aircraft. They have additional capabilities with which the tank commander must be competent. Both guns can be used in estimating range to targets, since the tracers in each weapon burn out at specific ranges. Also, the trajectories of 7.62 mm, HEP and HEAT ammunition are significantly similar so that the strike of coax rounds can be used as a fairly accurate indication of where these two main gun rounds will strike.

The machine guns can also be used for suppressive fire. The coax is sometimes fired by the gunner,while the tank commander uses the range finder, to keep the threat, or threats in the target area from accurate fire. Both the coax and the caliber .50 are also used to suppress and disrupt missile firing. Troops or vehicles firing guided missiles can be engaged with these weapons to disrupt tracking during missile flights.

Machine gun fire can sometimes provide information about the presence of hidden threats and potential targets. When the tank's position is likely to be known to the threat, the tank commander can use the coax, or the caliber .50 at longer ranges, to determine whether there are hard targets in an area, or whether threats of any kind are concealed. He, or the gunner fires into the area looking for explosions of ammunition or fuel, for fire coming from the area,and for ricochets as rounds strike hard surfaces. Although rounds may ricochet from rocks as well as from tanks and trucks, they can provide valuable information, where the terrain characteristics are reasonably well-known.

The coaxial machine gun and the .50 caliber are highly effective weapons whose operation requires relatively elementary training. Utilization of these weapons to their most tactical effect, however, requires extensive training in deciding on when, where,and how to use them to support the objectives of the mission.

5.4.1.5 Response To Threats. The entire crew must be alert to sense, evaluate, report and respond to events in the tactical environment, which support or reflect threat activity.

The tank commander's position in the turret, and his area of responsibility requires him especially, to be prepared to respond rapidly and effectively. Weapon flashes, tracers, smoke, flash, dust, glint and movement can all have great significance for the effectiveness and survival of the tank, and require not only that the commander see them, but that he also be able to perceive and respond to them within a tactical context. The ability to respond to events in a tactical context requires training in complex environments in which the context determines the meaning of individual events. Very few opportunities are available to tank commanders to experience and deal with complex tactical situations, because of limits in the availability of "tactical" terrain and threats, but the skill is crucial to success in tank combat.

Occasionally crews must react rationally to weapon strikes on the tank. Small arms, machine gun and anti-personnel artillery fire can be frightening and disruptive, but have relatively few implications for tank survival, provided the crew closes the hatches. Small arms and machine gun fire can be the prelude to the firing of more lethal weapons, delaying main gun fire or causing the crew to lose visibility by buttoning up. Small arms and machine gun strikes near or on the tank must result in careful defense, serious surveillance and return fire to disrupt more effective follow-up fire on the part of the threat.

Near misses by small arms are often heard by the commander and the loader, when they are exposed above the turret, and since small arms and machine gun rounds travel at supersonic velocities they are accompanied by audible shock waves. If the engine is not running, the commander or the loader may be able to range on the source of fire by estimating the time between the shock wave of the projectile and the report of the weapon firing it.

Near misses by anti-tank artillery can also be sensed because of the rushing sound produced by the shock waves. These require immediate action, either in returning fire or moving the tank to a less vulnerable position.

Impacts of anti-tank rounds on the tank can destroy it or damage it and may leave it incapable of continuing its mission unless the crew can respond in a disciplined manner to the direction of the tank commander, or of the gunner, if the tank commander becomes a casualty. The shock, noise and vibration of non-lethal hits can totally disrupt the crew's ability to perform, if the crew is not practiced in operating in the presence of adverse conditions. Such practice is not currently possible, but could enhance the ability of the M60A3 to operate in other more demoralizing circumstances.

Table 5-2 summarizes the tank commander's mission tasks and

TABLE 5-2 M60A3 TANK COMMANDER TRAINING OBJECTIVES

TASK	TRAINING OBJECTIVES	CRITICALITY	CUE REQUIREMENTS: VISUAL	CUE REQUIREMENTS: MOTION	CUE REQUIREMENTS: AURAL
1 ANALYZE TERRAIN					
1.1 SELECT ROUTE TO OBJECTIVE	IDENTIFY TERRAIN/CULTURAL FEATURES DEFINING OBJECTIVE; RECOGNIZE OBSTACLES, FIELDS OF FIRE, AREAS OF POTENTIAL THREAT CONCEALMENT AND LIKELY FIRING POSITIONS; SELECT GENERAL ROUTE; COMMUNICATE ROUTE TO DRIVER IN TERMS OF TERRAIN AND CULTURAL FEATURES. CORRELATE VISUAL SCENE WITH AREA MAP.	HIGH	TERRAIN VARIATIONS, RIDGES, HILLS, MEADOWS, WATER, WOODS; OBSTACLES IN FORM OF TREES, DITCHES, LOGS, ROCKS, BUILDINGS; RANGE FROM 100M TO 3000M, FOV ±45° FROM CENTERLINE OF HULL; BINOCULARS USED TO EVALUATE RANGE FROM 100M TO 3000M.	NONE	INTERCOM AND RADIO MESSAGES FOR CREW, PLATOON COORDINATION.
1.2 NAVIGATE TO OBJECTIVE	DIRECT DRIVER TO LANDMARKS AND CHECKPOINTS ALONG ROUTE.	MEDIUM; CAN BE DONE IN FCIS CONTEXT WITH SYMBOLIC FEATURES	IDENTIFIABLE FEATURES ALONG ROUTE; MAJOR TERRAIN AND/OR CULTURAL FEATURES WITHIN TC AND DRIVER FIELDS OF VIEW; RIDGES, WOODLINES, TREES, RAVINES, FIELDS, WOODLINES, FENCES, SLOPES; 100M to 3000M; FOV ±45°H.	FEEDBACK TO TC ABOUT TANK RESPONSE TO TERRAIN, SURFACES, CONTOURS & OBSTACLES; PITCH, ROLL; HEAVE & YAW MOTIONS OF MINOR IMPORTANCE IN DISTURBING TC BALANCE. VISUAL CUES TO LONGITUDINAL & LATERAL MOTION ARE ADEQUATE.	IC/RADIO MESSAGES; ENGINE, TRACK NOISES TO CONFIRM SPEED OF MOTION & TANK/TERRAIN INTERACTION.
1.3 ASSIST DRIVER IN ROUTE NEGOTIATION	RECOGNIZE OBSTACLES TO MOVEMENT AND AREAS OF POTENTIAL THREAT; RECOGNIZE TERRAIN SURFACE CHARACTERISTICS; USE ELEVATED VIEW TO DIRECT DRIVER AMONG OBSTACLES, OVER TERRAIN HAVING SURFACE AND SLOPE CHARACTERISTICS COMPATIBLE WITH TANK CAPABILITIES; DIRECT DRIVER ALONG CONCEALED ROUTES, WHEN POSSIBLE.	HIGH; MUST PERMIT TC TO USE HIS ELEVATED POINT OF VIEW.	SEE 1.2; CUES TO SURFACE TEXTURE, SLOPE	PITCH, ROLL FEEDBACK	SEE 1.2
1.4 DETECT TARGETS; ACQUIRE TARGETS FOR ENGAGEMENT	RECOGNIZE SIGNS OF POTENTIAL THREAT LOCATION AND ACTIVITY; RECOGNIZE PARTIALLY CONCEALED THREATS; ALERT CREW TO NATURE AND LOCATION OF THREAT; MAKE GROSS LAY OF MAIN/COAX GUNS FOR GUNNER IDENTIFICATION.	HIGH; TARGET DETAIL SUFFICIENT TO CLASSIFICATION AS A MINIMUM.	STATIONARY AND MOVING TARGETS AT RANGES OF FROM 300 TO 3000M; TARGET DETAIL TO INCLUDE: PARTIAL CONCEALMENT, DIRECTION OF MOTION, TYPE CLASSIFICATION, DIRECTION OF GUN, FIRING OR NON-FIRING; GUN OF TANK TO SUPPORT GROSS LAY FOR GUNNER IDENTIFICATION.	TANK MOTION (PITCH, ROLL) & TURRET MOTION FOR FEEDBACK IN CONTROL OF SLEW.	ENGINE TRACER, IC/RADIO, TURRET TRAVERSE, HYDRAULIC PUMP.
2 CONTROL TANK IN FORMATION					
2.1 ROUTE MARCH	RECOGNIZE POSITION OF TANK IN COLUMN; RECOGNIZE DISTANCE BETWEEN TANKS; DIRECT DRIVER TO EXTEND OR CLOSE INTERVAL.	LOW	ROAD AND/OR TERRAIN; TANK IMAGE TO FRONT INCLUDING GROSS DETAIL AND TAIL LIGHTS.	PITCH, ROLL, VIBRATION ASSOCIATED WITH SPEED AND SURFACE.	IC/RADIO; ENGINE & TRACK SOUNDS
2.2 TACTICAL MOVEMENT	RECOGNIZE LATERAL POSITION OF ADJACENT TANKS; COORDINATE MOVEMENT TO PROVIDE COVERING FIRE FOR MOVING TANK, AND TO MOVE UNDER COVERING FIRE OF COVERING TANK; RECOGNIZE EFFECT OF WEAPONS OF ADJACENT TANKS.	MEDIUM	SEE 1.1, 1.2, 1.3, 1.4; FRIENDLY ADJACENT TANK MANEUVERING IN COORDINATION WITH RADIO MESSAGES; FRIENDLY TANK FIRE AND WEAPON EFFECTS; ADJACENT TANK MOVING IN AND OUT OF COVER.	SEE 1.2 THROUGH 1.4	IC/RADIO, ENGINE & TRACK SOUNDS; SOUNDS OF ADJACENT TANK FIRE.

2.1 ROUTE MARCH	RECOGNIZE POSITION OF TANK IN COLUMN; RECOGNIZE DISTANCE BETWEEN TANKS; DIRECT DRIVER TO EXTEND OR CLOSE INTERVAL.	LOW	ROAD AND/OR TERRAIN; TANK IMAGE TO FRONT INCLUDING GROSS DETAIL AND TAIL LIGHTS.	PITCH, ROLL, VIBRATION ASSOCIATED WITH SPEED AND SURFACE.	IC/RADIO; ENGINE & TRACK SOUNDS	
2.2 TACTICAL MOVEMENT	RECOGNIZE LATERAL POSITION OF ADJACENT TANKS; COORDINATE MOVEMENT TO PROVIDE COVERING FIRE FOR MOVING TANK, AND TO MOVE UNDER COVERING FIRE OF COVERING TANK; RECOGNIZE EFFECT OF WEAPONS OF ADJACENT TANKS.	MEDIUM	SEE 1.1, 1.2, 1.3, 1.4; FRIENDLY ADJACENT TANK MANEUVERING IN COORDINATION WITH RADIO MESSAGES; FRIENDLY TANK FIRE AND WEAPON EFFECTS; ADJACENT TANK MOVING IN AND OUT OF COVER.	SEE 1.2 THROUGH 1.4	IC/RADIO, ENGINE & TRACK SOUNDS; SOUNDS OF ADJACENT TANK FIRE.	
3 OPERATE WEAPON SYSTEMS						
3.1 BORESIGHT AND ZERO MAIN, COAX, CAL. 50	ALIGN WEAPON BORES WITH BORESIGHT TARGET; ADJUST SIGHT RETICLES TO COINCIDE WITH BORESIGHT TRANSIT. FIRE ZEROING ROUNDS, ADJUST RETICLES TO GROUP CENTERS; CONFIRM ZERO.	MEDIUM; ONLY SPARSE DETAIL REQUIRED	CROSSHAIRS (THREADS) IN MAIN GUN MUZZLE, BORESIGHT TARGET VIEWED THROUGH TUBE, PERISCOPE AND TELESCOPE; BORESIGHT TARGET IN VIEW THROUGH MUZZLES OF CAL. 50 AND COAX.	NONE	NONE	
3.2 CONTROL FIRE OF MAIN AND COAX GUNS	ISSUES INITIAL FIRE COMMAND TO DESIGNATED TARGET AND TO ALERT LOADER, GUNNER AND DRIVER; RECOGNIZES TARGET TYPE AND PRIORITY, SELECTS WEAPON, AMMUNITION AND FIRING MODE; RECOGNIZES TERRAIN AND COVER AVAILABLE; MAY DIRECT DRIVER TO FIRING POSITION OR DIRECTION OF MOVEMENT DURING STABILIZED FIRING. RANGES WITH LASER RANGEFINDER OR USES BATTLESIGHT. RECOGNIZES CHANGES IN TARGET PRIORITIES DUE TO WEAPON EFFECTS OR TO CHANGES IN THREAT DEPLOYMENT; ISSUES COMMAND TO CEASE FIRE OR TO ENGAGE NEW TARGET; MAKES GROSS LAY AS REQUIRED TO ASSURE TARGET IDENTIFICATION BY GUNNER.	HIGH; ESSENCE OF FCIS TRAINING PROBLEM	MULTIPLE TARGETS AT RANGES OF FROM 300M to 3000M; TERRAIN AND VEGETATION PROVIDING CONCEALMENT, FIELDS OF FIRE AND TERRAIN IRREGULARITIES FOR COVER; TARGET DETAIL TO SUPPORT DISCRIMINATION OF TARGET TYPE, DIRECTION OF GUN, FIRING/NON-FIRING, MOVING AND STATIONARY FOV $\pm 60°$H FROM HULL CENTERLINE; DETAIL CONCENTRATED AROUND BATTLESIGHT (1200M) NEAR (400M) OR FAR (2500M) RANGES. TERRAIN DETAIL IN 30-100M FOR CRITIQUE OF DRIVER SELECTION OF FIRING POSITION IN COVER OR HULL-DOWN POSITION.	ENGINE, TRACK VIBRATION IN RELATION TO TERRAIN SURFACE, SPEED, SCREENING; TURRET ROTATION & BRAKING (PITCH, ROLL, YAW).	ENGINE TRACER IN RELATION TO TERRAIN SURFACE; MAIN GUN BREECH.	
3.3 ENGAGE TARGET WITH MAIN GUN	DETECT, RECOGNIZE TARGET; DECIDE TO ENGAGE FROM TC POSITION; ACQUIRE TARGET IN RANGEFINDER, PERISCOPE OR THERMAL SIGHT; LAY GUN FOR BATTLESIGHT ENGAGEMENT, OR RANGE WITH LRF FOR PRECISION ENGAGEMENT; DIRECT SELECTION OF AMMUNITION IN COMPUTER; ALERT CREW, SELECT FIRING MODE, DIRECT DRIVER TO STOP OR CONTINUE MOVING; ENGAGE TARGET, SENSE ROUND, CONTINUE FIRING OR CEASE FIRE, DEPENDING ON WEAPON EFFECT.	HIGH	SEE 3.2; FLASH AND OBSCURATION OF OWN GUN; TRACER, IMPACT (SHORT, TARGET OR OVER); FLASH, SMOKE, TRACER, IMPACT OF ADJACENT TANK; FLASH, SMOKE OF THREAT FIRING; MISSILE BODY OF THREAT ATGM.	PITCH, ROLL ASSOCIATED WITH TERRAIN, STEERING, STOPPING, STARTING; TURRET ROTATION; SHOCK OF MAIN GUN FIRING.	ENGINE, TRACK MAIN GUN FIRING; IC/RADIO, RECOIL & SHELL CASING SOUNDS; TURRET EXHAUST BLOWER, TURRET TRAVERSE, GUN ELEVATION.	
3.4 ENGAGE TARGET WITH COAX GUN	DETECT, RECOGNIZE AREA TARGET; DECIDE TO ENGAGE FROM TC POSITION; ACQUIRE TARGET IN RANGEFINDER, PERISCOPE, THERMAL SIGHT, VISION BLOCK OR DIRECT VISION; DIRECT DRIVER IN ROUTE AND MODE OF MOVEMENT; ENGAGE TARGET AND SENSE WEAPON EFFECT; OBSERVE TRACER AND ADJUST FIRE AS NECESSARY, TRAVERSE AND ELEVATE/DEPRESS TURRET AS REQUIRED FOR TARGET COVERAGE AND EFFECT.	HIGH	SEE 3.2, 3.3, AREA TARGETS (TROOPS, LIGHTLY ARMORED VEHICLES)	SEE 3.3	SEE 3.3; SOUND OF COAX FIRING	
3.5 ENGAGE TARGET WITH CAL. 50	DETECT, RECOGNIZE CAL. 50 TARGET; ACQUIRE TARGET IN PERISCOPE, THERMAL SIGHT OR VISION BLOCK; ISSUE FIRE AND DRIVING COMMANDS; ENGAGE TARGET, OBSERVE TRACER AND ADJUST FIRE AS NECESSARY; TRAVERSE CUPOLA, [illegible]	MEDIUM	SEE 3.2, 3.3; CAL. 50 TARGETS; INDIVIDUAL LIGHTLY-ARMORED VEHICLES, PERSONNEL, MUZZLE FLASH (NIGHT), TRACER	SEE 3.2; CUPOLA ROTATION	CAL. 50 FIRING, ENGINE, TRACK IN RELATION TO TERRAIN; IC/RADIO, CUPOLA TRAVERSE	

	BLOCK OR DIRECT VISION; DIRECT DRIVER IN ROUTE AND MODE OF MOVEMENT; ENGAGE TARGET AND SENSE WEAPON EFFECT; OBSERVE TRACER AND ADJUST FIRE AS NECESSARY, TRAVERSE AND ELEVATE/DEPRESS TURRET AS REQUIRED FOR TARGET COVERAGE AND EFFECT.				
3.5 ENGAGE TARGET WITH CAL. 50	DETECT, RECOGNIZE CAL. 50 TARGET; ACQUIRE TARGET IN PERISCOPE, THERMAL SIGHT OR VISION BLOCK; ISSUE FIRE AND DRIVING COMMANDS; ENGAGE TARGET, OBSERVE TRACER AND ADJUST FIRE AS NECESSARY; TRAVERSE CUPOLA, ELEVATE/DEPRESS CAL. 50 AS REQUIRED FOR TARGET EFFECT.	MEDIUM	SEE 3.2, 3.3; CAL. 50 TARGETS; INDIVIDUAL LIGHTLY-ARMORED VEHICLES, PERSONNEL, MUZZLE FLASH (NIGHT), TRACER	SEE 3.2; CUPOLA ROTATION	CAL. 50 FIRING, ENGINE, TRACK IN RELATION TO TERRAIN; IC/RADIO, CUPOLA TRAVERSE
3.6 OPERATE GRENADE LAUNCHER SYSTEM	RECOGNIZE THREAT ARRAY AND TERRAIN CHARACTERISTICS LEADING TO TANK VULNERABILITY; SELECT MOVEMENT ROUTE; DIRECT DRIVER TOWARD TERRAIN AND/OR CULTURAL FEATURES DEFINING ROUTE; ESTIMATE WIND SPEED AND DIRECTION, ROTATE TURRET FOR OPTIMUM SCREENING EFFECT OF SMOKE GRENADES; LAUNCH GRENADES AND OBSERVE SCREENING EFFECT; DIRECT DRIVER IN TAKING ADVANTAGE OF SCREEN.	MEDIUM	THREATS IN AREA FROM 300-3000M; THREAT FIRING (FLASH, SMOKE) WIND EFFECTS ON DUST, SMOKE, AND FOLIAGE; SMOKE FROM GRENADES IN AREA FROM 30M TO 50M, OBSCURING THREAT; WIND EFFECTS ON GRENADE SMOKE (DRIFTING TO REVEAL THREATS: TANK MOTION EFFECTS (MOVE THROUGH, AWAY FROM SMOKE) TERRAIN SURFACE & FEATURES IN 30M-100M RANGE; COVER AND CONCEALMENT.	PITCH, ROLL WITH MOTION OVER TERRAIN; ENGINE, TANK VIBRATION VARYING W/ TERRAIN SURFACE; SMALL ARMS STRIKES ON TANK (mg)	ENGINE, TRACK SOUND OF GRENADE LAUNCHER; SMALL ARMS STRIKES ON TANK (mg)
4 EMPLOY MACHINE GUN SYSTEMS					
4.1 USE MACHINE GUN FOR RANGING (COAX OR CAL. 50)	ENGAGE TARGET OR TARGET AREA WITH COAX MACHINE GUN; NOTE RANGE OF TRACER BURNOUT; ESTIMATE RANGE TO TARGET AREA AS COMPARED WITH BURNOUT RANGE OF AMMUNITION.	MEDIUM	COAX/CAL. 50 TRACER WITH BURNOUT AT APPROPRIATE RANGE; TARGETS AND/OR TERRAIN FEATURES IN VICINITY OF TRACER BURNOUT.	TURRET/CUPOLA TRAVERSE	TURRET/CUPOLA TRAVERSE; COAX OR CAL. 50 FIRING
4.2 USE INCENDIARY EFFECTS OF CAL. 50	IDENTIFY VEGETATION OSCURING VIEW TO TERRAIN OR TARGET AREA OF INTEREST; FIRE CAL. 50 INTO AREA EMPLOYING INCENDIARY AMMUNITION; OBSERVE TRACER AND TARGET EFFECT; ADJUST AS NECESSARY; OBSERVE BURNING OF TARGET AREA; SEARCH FOR THREATS OR TERRAIN FEATURES OF INTEREST.	LOW	CAL. 50 TRACER IN VEGETATION, 500-1500M; BURNING VEGETATION DETECTED IN SCENE.	TURRET/CUPOLA TRAVERSE	ENGINE SOUND; TURRET, CUPOLA TRAVERSE; HYDRAULIC PUMP; IC/RADIO; CAL. 50 FIRING
4.3 PERFORM RECONNAISSANCE BY FIRE	IDENTIFY AREA OF POSSIBLE THREAT CONCEALMENT; ESTIMATE RANGE OR USE LRF TO DETERMINE RANGE SELECT COAX OR CAL. 50, DEPENDING ON RANGE TO TARGET AREA; FIRE INTO AREA; OBSERVE TRACER RICOCHET, SMOKE, DUST, MOVEMENT OR OTHER INDICATION OF THREAT; PREPARE TO ISSUE COMMAND FOR MAIN GUN FIRE ON TARGETS REVEALED BY RECONNAISSANCE BY FIRE.	MEDIUM	TERRAIN W/COVER (VEGETATION) IN AREA AROUND 300M-1000M; COAX TRACER, RICOCHETS IN SPECIFIC VEGETATION AREAS; SMOKE (DIESEL), DUST, MOVEMENT OF VEGETATION IN TARGET AREA, APPEARANCE OF TANK FROM COVER IN TARGET AREA.	TURRET TRAVERSE	ENGINE; TURRET TRAVERSE; COAX FIRING; HYDRAULIC PUMP; IC/RADIO
4.4 PERFORM SUPPRESSIVE FIRE	IDENTIFY PERSONNEL TARGETS; EVALUATE THREAT LEVEL; EMPLOY COAX OR CAL. 50 TO DESTROY PERSONNEL TARGETS OR TO PREVENT LAUNCH OF ANTI-TANK WEAPONS; OBSERVE WEAPON EFFECTS, DIRECT DRIVER TO MOVE INTO COVER.	MEDIUM	TERRAIN/CULTURAL FEATURES IN COAX/CAL. 50 RANGE (200-1200M); PERSONNEL TARGETS; TARGET FIRING (mg, ATGM); COAX/CAL. 50 TRACER; ATGM MISSILE BODY	ENGINE/TRACK OVER TERRAIN; TURRET, CUPOLA TRAVERSE	SMALL ARMS STRIKES ON TANK ENGINE, TRACK COAX/CAL. 50; IC/RADIO
5 RESPOND TO THREAT WEAPON NEAR-MISSES, NON-LETHAL HITS	RECOGNIZE POTENTIAL LETHALITY OF NEAR-MISSES AND NON-LETHAL HITS; SENSE SOURCES OF FIRE; EVADE AND/OR ENGAGE MOST LETHAL THREATS	HIGH	THREAT FIRE (SMOKE, DUST, FLASH, ATGM MISSLE BODY)	VIBRATION/SHOCK FROM MAIN GUN, ATGM HITS	SMALL ARMS, MAIN GUN, HITS AND NEAR MISSES, ATGM HITS

13

the associated training objectives. The table also rates the criticality of the tasks and indicates the visual, motion,and aural cues necessary to support training.

5.4.2 Gunner. The main gun and the coaxial machine gun are fired by the gunner at the direction of the tank commander. The gunner acquires targets in his sights and applies the correct procedure for entering range, ammunition,and lead values into the computer to maximize chances of first-round hits on targets. When the first round or burst is not enough to destroy the target, the gunner re-lays the gun, using corrective information obtained in the previous firing to bring accurate fire on the target.

The gunner also maintains surveillance of the area forward of the turret, to the extent possible, using his unity-power window, his periscope, thermal sight,and telescope. Each instrument has a narrow field of view, limiting the ability of the gunner to search large areas rapidly. The magnification provided in the optical system makes it possible for the gunner to examine distant areas in some detail, however. Frequently, in tank movement, the gunner traverses the turret and elevates the main gun to permit him to search, while the commander and loader search their own areas of responsibility.

The gunner can learn many of his procedures and responsibilities in relatively simple settings, but some must be integrated within the responsibilities of the rest of the crew to assure proper and effective timing of gunner procedures. The driver and the tank commander, in particular, can make decisions strongly affecting the gunner, to which he must learn to respond. The gunner does not need to make many decisions, but he must be able to perform his tasks quickly and accurately, to assure maximum effectiveness of the tank, and to minimize its vulnerability. The gunner can learn many of his skills in less complex settings than a full crew interaction setting, but the complex interactions among the gunner and the other three crew members require that the gunner practice extensively in a total crew setting. Practice is needed in fitting gunner tasks to crew and mission requirements, within stringent time constraints, and in a difficult operating environment. Specifically, the gunner needs to be trained within a total crew context in four general task areas.

5.4.2.1 Surveillance. It is difficult for the gunner to maintain adequate surveillance of the area from his position, especially when the tank is moving. His magnified sighting systems, however, give him a good view of distant areas, especially when the stabilization system is on. Thus,he can effectively supplement the surveillance performed by the loader and the commander, reporting events appearing at ranges to 3,000 meters and beyond. When the sights are unstabilized, the gunner has diffculty in evaluating the available visual scene, but can still sense and report events of significance

to the tank and its mission, if he is free to traverse the turret and elevate and depress the sights.

The gunner's surveillance task is difficult;largely because of the narrow field of view available to him, and because of the problem of seeing with the sights moving with respect to the scene (unstabilized) and, with the eyepieces moving with respect to his head. Little real-world practice is available in developing this skill, but it is crucial to the success of the tank in its assigned missions. The gunner must be able to see and interpret cues to target activity so that he can alert the crew, and engage threats before they can engage the tank.

5.4.2.2 Target Acquisition. Usually the tank commander detects targets to be engaged, issuing a command to bring fire on the target. As he initiates the fire command, he slews the turret to place the target within the gunner's field of view so that the gunner can acquire sight on, and fire at the target. As the tank commander slews the turret,he describes the target and if it is not obvious, describes its position with respect to some landmark in the vicinity. Part of the gunner's training is in learning to recognize the way the commander describes the target so that he can acquire and engage it with minimum delay.

In some cases, the gunner acquires a target on his own initiative, laying his sights on it while alerting the tank commander who acquires it from the gunner's initial alert. The gunner, like the commander, must learn to recognize and interpret minimal cues to threat activity so that targets can be acquired and engaged at maximum range. In either case, the level of coordination required between the gunner and the tank commander, with the number of engagement modes available to them, requires extesnive practice, very little of which is available in real-world training settings.

5.4.2.3 Weapon System Operation. The gunner fires the main gun and the coaxial machine gun. He can fire five different kinds of rounds in the main gun and he can fire from a battlesight setting or with precise range entered into the ballistic computer. Each round has its own characteristics relevant to computer setting and the sensing and adjustment of rounds fired. The basic armor training course will provide good training for gunners in main gun firing, but will not provide the gunner with adequate opportunities to practice main gun operation in most of the engagement situations (see Table 5-3) he might reasonably expect to encounter in tank combat. The gunner can fire the main gun from his periscope, thermal sight or from his telescope. He can fire on the move, maintaining his eye in the exit pupil of the sight eyepiece by resting his helmet on the browpiece, and he can fire at moving and stationary targets. When he fires at a moving target in the unstabilized move, he must apply lead by manually or electrically

traversing the turret, tracking the target with the proper lead-line. When firing in the stabilized mode, he need only make initial tracking control inputs. He may need to modify these initial inputs if target apparent velocity changes, but the computer does most of the tracking task.

Telescope firing is somewhat of a problem, since the gunner must enter range data by elevating the telescope to intersect the target with the proper range line. In addition, he may also have to track the target with a lead line in the telescope reticle.

The gunner also fires the coaxial machine gun on command. He fires the coax at area targets and at lightly-armored targets at relatively close range. His use of the coax is especially important because he may use it to fire suppressive fire while the commander fires the main gun, keeping the target, or other threats in the target area from returning fire during the sighting and firing process. He may also fire the coax to determine if hard targets are concealed in vegetation or behind thin-walled buildings, by watching for ricochets or secondary explosions. Frequently, the gunner will employ the coax against troops, to keep them from launching weapons against the tank, or to support friendly infantry elements.

5.4.2.4 Range Card Firing. The gunner works with the tank commander in developing range cards to be used for laying pre-planned fire on suspected target areas, primarily during periods of limited visibility. The gunner prepares a range card by writing the range, azimuth and elevation to specific target areas on a sketch or grid representing the tank's areas of responsibility. Azimuth and elevation are recorded in reference to a nearby aiming point. When fire is called for in the area, the gunner indexes the ammunition to be fired in the ballistic computer, and elevates and traverses the gun to the appropriate elevation and azimuth reading. A fixed procedure is followed to assure coverage of the target area without visual contact, but both the commander and the gunner attempt to sense the effects of rounds fired, using the flash generated by the impact and/or explosion of rounds in the target area. In some cases, flares or searchlights are used to illuminate the target area before or during the engagement, so that fire can be accurately adjusted.

Range card preparation is difficult for gunners to learn, but adequate training requires only simple training settings. Practice in fire adjustment and in the continuation of the mission in a variety of unexpected circumstances is rare, even though it is crucial to crew effectiveness. Gunners, loaders, drivers, and tank commanders need to practice the actions required to continue range card missions when the position cannot be maintained, when expected illumination is not provided, or when supporting units are neutralized.

Table 5-3 summarizes the gunner's mission tasks and the associated training objectives. The table also rates the criticality of the tasks and indicates the visual, motion,and aural cues necessary to support training.

TABLE 5-3 M60A3 GUNNER TRAINING OBJECTIVES

TRAINING OBJECTIVES	CRITICALITY	CUE REQUIREMENTS: VISUAL	CUE REQUIREMENTS: MOTION	CUE REQUIREMENTS: AURAL
1 TERRAIN EVALUATION				
RECOGNIZE TERRAIN, CULTURAL AND VEGETATION FEATURES CAPABLE OF CONCEALING AND SUPPORTING THE MOVEMENT OF THREATS	HIGH	HILLS, RIDGES, TREELINES, FIELDS, FOLIAGE RAVINES, BUILDINGS. (UNITY AND POWERED OPTICS.		
RECOGNIZE THE TERRAIN, CULTURAL AND VEGETATION FEATURES USING THE TANK THERMAL SIGHT.	HIGH	ABOVE CUES IN FORM OF THERMAL SIGHT, IMAGERY, CORRELATED WITH NORMAL VISIBLE-RANGE IMAGES.		
RECOGNIZE TERRAIN, TERRAIN SURFACES AND CULTURAL AND VEGETATION FEATURES CAPABLE OF CONCEALING OR SUPPORTING THE MOVEMENTS OF THE TANK; ASSIST DRIVER IN SELECTION OF ROUTES AND INFORMATION OF OBSTACLES AND SURFACES.	MEDIUM	ABOVE CUES; CUES TO SURFACE CHARACTERISTICS VISIBLE IN THERMAL AND PERISCOPE SIGHTS; SURFACES TO INCLUDE ROAD, HARD DIRT, MUD, SNOW AND ICE.	PITCH, ROLL, VIBRATION ASSOCIATED WITH THE NEGOTIATION OF EACH SURFACE TYPE.	TRACER, ENGINE AND TRANSMISSION SOUNDS ASSOCIATED WITH MOVEMENT OVER EACH TYPE OF SURFACE.
2 TARGET DETECTION				
RECOGNIZE THREAT INDICATIONS	HIGH	SMOKE, DUST, GLINT, MOVEMENT OF TARGETS, DUST OR FOLIAGE, VISIBLE IN UNITY AND POWERED OPTICS.		
RECOGNIZE THREATS AND THREAT TYPES	MEDIUM	TANKS, TRACKS, ARMORED PERSONNEL CARRIERS, FORTIFICATION, HELICOPTERS, HIGH-PERFORMANCE AIRCRAFT, VISIBLE IN UNITY AND POWERED OPTICS.		
ACQUIRE TARGETS DESIGNATED BY COMMANDER; RECOGNIZE LOCATION BY MEANS OF TARGET IMAGE, PROXIMITY TO DESIGNATED TERRAIN, CULTURAL OR VEGETATIVE FEATURES	HIGH	TARGETS AND PROMINENT LANDMARK FEATURES, VISIBLE IN POWERED OPTICS (PERISCOPE, TELESCOPE, THERMAL SIGHT)		INTERCOM
3 THREAT ENGAGEMENT				
ENGAGE THREATS WITH MAIN, COAX GUNS WHILE STATIONARY AND WHILE MOVING IN STABILIZED AND UNSTABILIZED MODE.	HIGH	WEAPON FLASH, SMOKE, OBSERVATION AND TRACER; ROUND IMPACT EFFECTS AND TRACER BURNOUT	PITCH, ROLL, VIBRATION ASSOCIATED WITH VARIOUS TERRAIN TYPES AND FIRING IN MOVING ENGAGEMENTS; YAW ONSETS ASSOCIATED WITH TURRET SLEW. SIGHT RECOIL IN MAIN GUN FIRING	WEAPON SOUNDS (BREECH, FIRING; FIRE COMMANDS AND SENSING VIA INTERCOM)
ENGAGE MOVING TARGETS **WHILE STATIONARY, MOVING**	HIGH	ABOVE CUES; TARGET MOTION (CROSS-RANGE, **HEAD-ON AND DIAGONAL)**	PITCH, ROLL, VIBRATION IN MOVING ENGAGEMENTS; **SIGHT RECOIL IN MAIN GUN**	ABOVE CUES

CAPABLE OF CONCEALING AND SUPPORTING THE MOVEMENT OF THREATS		OPTICS.		
RECOGNIZE THE TERRAIN, CULTURAL AND VEGETATION FEATURES USING THE TANK THERMAL SIGHT.	HIGH	ABOVE CUES IN FORM OF THERMAL SIGHT, IMAGERY, CORRELATED WITH NORMAL VISIBLE-RANGE IMAGES.		
RECOGNIZE TERRAIN, TERRAIN SURFACES AND CULTURAL AND VEGETATION FEATURES CAPABLE OF CONCEALING OR SUPPORTING THE MOVEMENTS OF THE TANK; ASSIST DRIVER IN SELECTION OF ROUTES AND INFORMATION OF OBSTACLES AND SURFACES.	MEDIUM	ABOVE CUES; CUES TO SURFACE CHARACTERISTICS VISIBLE IN THERMAL AND PERISCOPE SIGHTS; SURFACES TO INCLUDE ROAD, HARD DIRT, MUD, SNOW AND ICE.	PITCH, ROLL, VIBRATION ASSOCIATED WITH THE NEGOTIATION OF EACH SURFACE TYPE.	TRACER, ENGINE AND TRANSMISSION SOUNDS ASSOCIATED WITH MOVEMENT OVER EACH TYPE OF SURFACE.
2 TARGET DETECTION				
RECOGNIZE THREAT INDICATIONS	HIGH	SMOKE, DUST, GLINT, MOVEMENT OF TARGETS, DUST OR FOLIAGE, VISIBLE IN UNITY AND POWERED OPTICS.		
RECOGNIZE THREATS AND THREAT TYPES	MEDIUM	TANKS, TRACKS, ARMORED PERSONNEL CARRIERS, FORTIFICATION, HELICOPTERS, HIGH-PERFORMANCE AIRCRAFT, VISIBLE IN UNITY AND POWERED OPTICS.		
ACQUIRE TARGETS DESIGNATED BY COMMANDER; RECOGNIZE LOCATION BY MEANS OF TARGET IMAGE, PROXIMITY TO DESIGNATED TERRAIN, CULTURAL OR VEGETATIVE FEATURES	HIGH	TARGETS AND PROMINENT LANDMARK FEATURES, VISIBLE IN POWERED OPTICS (PERISCOPE, TELESCOPE, THERMAL SIGHT)		INTERCOM
3 THREAT ENGAGEMENT				
ENGAGE THREATS WITH MAIN, COAX GUNS WHILE STATIONARY AND WHILE MOVING IN STABILIZED AND UNSTABILIZED MODE.	HIGH	WEAPON FLASH, SMOKE, OBSERVATION AND TRACER; ROUND IMPACT EFFECTS AND TRACER BURNOUT	PITCH, ROLL, VIBRATION ASSOCIATED WITH VARIOUS TERRAIN TYPES AND FIRING IN MOVING ENGAGEMENTS; YAW ONSETS ASSOCIATED WITH TURRET SLEW. SIGHT RECOIL IN MAIN GUN FIRING	WEAPON SOUNDS (BREECH, FIRING; FIRE COMMANDS AND SENSING VIA INTERCOM)
ENGAGE MOVING TARGETS WHILE STATIONARY, MOVING	HIGH	ABOVE CUES; TARGET MOTION (CROSS-RANGE, HEAD-ON AND DIAGONAL)	PITCH, ROLL, VIBRATION IN MOVING ENGAGEMENTS; SIGHT RECOIL IN MAIN GUN FIRING	ABOVE CUES
SENSE FALL OF SHORT; RESPOND TO CREW OR OBSERVER SENSINGS; APPLY CORRECTIONS AND BURST-ON-TARGET	HIGH	TRACERS AND ROUND IMPACT; IMPACT CHARACTERISTICS OF AMMUNITION TYPES AND IMPACT POINTS (NONE VS. SOFT TARGETS, EARTH)	PITCH, ROLL, VIBRATION ASSOCIATED WITH MAIN GUN FIRING AND MOTION IN MOVING ENGAGEMENTS; YAW ONSETS IN TURRET SLEW	INTERCOM RADIO
PREPARE A RANGECARD	MEDIUM	PROMINENT TERRAIN FEATURES FROM 800 to 3000M		
FIRE FROM RANGECARD WITHOUT ILLUMINATION	MEDIUM	WEAPON TRACERS AND IMPACT EFFECTS IN TARGET AREA; TARGETS VISIBLE IN FLASHES OF WEAPON EFFECTS.		INTERCOM
FIRE FROM RANGECARD WITH ILLUMINATION; ADJUST AS REQUIRED	MEDIUM	TARGETS VISIBLE IN SEARCH LIGHT BEAM OR FLARE ILLUMINATION		

74

5.4.3 Loader. The loader loads and maintains the main gun and the coaxial machine gun. When possible, he also searches the area around the tank for possible threats, by standing with his head out of the loader's hatch, or by looking through his unity-power periscope, mounted in the hatch. Under some circumstances, he also engages surface and air targets with his 7.62 caliber machine gun. Operation of the machine gun requires him to be out of the hatch, so that he cannot fire it during NBC or other closed-hatch operations.

In some ways, the physical stresses on the loader and the physical aspects of his job make it the most demanding in the crew. The loader's skill is also very critical to the crew, as he selects and loads ammunition into the main gun, not only in loading correctly and safely, but in loading rapidly in sustained fire missions. In some circumstances, rate of fire and survival time on the battlefield are directly related, with rate of fire primarily the responsibility of the loader.

The M60A3's stabilization system permits the gunner and the tank commander to engage targets while the tank is moving. The driver stabilizes the tank as well as possible during moving engagements, by selecting a smooth route and a constant rate of speed. The tank can rarely be stable and at the same time be maintained in the least vulnerable position. Thus the turret floor, during moving engagements, is quite likely to be a poor platform for the loader as he manipulates the main gun ammunition.

If the loader loses his footing in the moving turret, or if he slips on an expended shell case lying on the floor, he could drop and damage a round, causing a subsequent misfire. He could also be struck and injured by the breech of the gun as it recoils. Since the stabilized gun moves in elevation with respect to the turret floor, as the tank moves over uneven ground, the loader could also be injured by that motion, and he could injure his hand as he pushes the round against the extractors in the moving gun. For all of these reasons, the loader tends to be cautious and, without extensive practice and wanting confidence, he tends to be slow and deliberate.

The loader maintains the coaxial machine gun, and monitors its performance. Coax stoppages can result from dirty ammunition, a ruptured case, incorrect headspace, propellant residue,or a bad round in the belt. The loader must recognize the cause of the stoppage by sound, and also by the gun's performance as he takes immediate action, so that he can correct the problem as rapidly as possible. He also monitors the ammunition in the coax ammunition (banana) box and links a new belt to the old between engagements to keep the gun from running out of ammunition during an engagement. Coax stoppages can be as disastrous as stoppages of the main gun, because the coax is designed to destroy and suppress some of the more severe threats to the tank personnel.

The tank is also vulnerable to some main gun targets unless their fire can be temporarily suppressed by the coax. Therefore, the loader's abilit to support coax operations is vital to the tank and its missions.

The loader has four primary functions requiring training in tactical settings. He has many other responsibilities for tank and weapon system maintenance, but they do not involve intimate interactions with the mission, the tactical environment or with the rest of the crew.

5.4.3.1 Load Main and Coax Guns. The loader loads the main gun on command from the tank commander, who identifies the target to be engaged and the ammunition to be used. The loader identifies the ammunition by shape and color coding, unlocks it from the ready rack, loads it into the main gun, sets the main gun switch to "FIRE" and announces "UP" so that the commander and the gunner know the gun is ready to be fired. The loader makes a setting on the anti-personnel (Beehive) round to determine its bursting range, but none of the other ammunition needs any such manipulation.

The loader also loads and maintains the coaxial machine gun. He monitors the expenditure of ammunition, and replenishes the coax before the ammunition box runs out. The loader determines whether and when the gunner and commander have ammunition available to fire. Effective crew interaction requires the gunner to respond rapidly and accurately to fire commands, to anticipate commands when possible, and to constantly monitor the coax ammunition supply, so that the gunner and commander have the conditions they need to perform their tasks.

Extensive practice is required by the loader in loading in the unstable environment of the moving tank turret. This training should be provided prior to training in crew interaction, but the crew interaction training setting should incorporate major environmental effects on the loader. These are required to permit the loader to learn to time and control his responses realistically, and to permit the gunner and the commander to learn to anticipate and deal with stress-produced discontinuities in loader performance. The primary stresses on the loader in loading the two guns are time and turret motion; he must learn to sense and deal with each as he performs as a member of the team.

5.4.3.2 Response to Weapon Malfunctions. The main gun and the coax can malfunction, for reasons essentially out of the control of the crew. Many of these malfunctions can be cleared by taking appropriate immediate action, although some, inevitably, take more detailed maintenance than can be performed during a mission. If the main gun misfires, the round can be removed and exchanged with another. If it still misfires, it must be

repaired at some other time. The coaxial machine gun can also malfunction due to a bad round, a bent round, build-up of excessive residue, incorrect headspace, or dirt in the ammunition. Some stoppages can be cleared by recharging the gun, but in some cases, a burst case can require the loader to change barrels.

Unskilled diagnosis and correction of coax stoppages can take appreciable amounts of time; in combat, time is frequently at a premium, making skilled diagnosis and corrective actions extremely important. Many coax failures can be diagnosed by the sounds associated with them. The loader can learn to recognize these sounds in settings other than in a full crew interaction training device, but he must be required to deal with them in the full crew situation, again to permit him to learn to integrate his performance with that of the rest of the crew, and to permit the rest of the crew to learn to anticipate and work around his performance. It should be possible for the coaxial machine gun to simulate stoppages for various reasons, and to require the correct remedial procedure, but it is not necessary that the loader practice each of these in the crew interaction simulator.

5.4.3.3 Surveillance. During some parts of the mission, the loader will take part in the surveillance of the area,searching for threats and signs of threat activity. He will also spend some time assisting the driver in evaluating terrain, terrain features, obstacles and routes. The most important aspect of the loader's surveillance task for crew interaction, is in learning that the rest of the crew depends on his eyes in detecting threats to the tank as rapidly as possible. During periods of loader surveillance, the loader must be presented with signs of potential threat activity, and with threat images. Since some commanders, training specific crews, may require the loader to use the tank's binoculars, the loader should have access to them as well as to his own unity-power periscope.

In the tank, the loader's surveillance area includes the flank and an area to the rear of the tank; in training in the full crew simulator, it is most important that the loader see significant events throughout the visual scene available to him; it is not important that the entire scene be available as it would be in the tank, however. The objective is to teach the loader to look and observe where he can, when he can, and to respond to what he sees.

5.4.3.4 Machine Gun Fire. The loader's 7.62mm machine gun is used to engage area targets during periods when the main gun would not be employed. It is also used to engage low-flying aircraft. The hit probability of the 7.62 on aircraft is low, but the weapon is effective in keeping helicopters from approaching the tank. The 7.62mm can also disrupt helicopters launching and guiding ATGM's, reducing the danger to the tank. Loader training in 7.62 gunnery will require specific training in simpler settings, but the loader must use the 7.62 in the

Table 5-4 M60A3 Loader Training Objectives

TASK	TRAINING OBJECTIVES	CRITICALITY	CUE REQUIREMENTS VISUAL	CUE REQUIREMENTS MOTION	CUE REQUIREMENTS AURAL
1 LOAD MAIN AND COAX GUNS	SELECT AND LOAD MAIN GUN ROUNDS AS DESIGNATED BY COMMANDER IN MOVING AND STATIONARY TURRET; PERFORM QUICKLY AND SAFELY, AVOIDING CONTACT WITH BREECH AND BREECH BLOCK	HIGH	SHAPE, COLOR CODE OF ROUNDS; VISUAL CUES ASSOCIATED WITH BREECH	BREECH MOVING IN TERRET; TURRET PITCH, ROLL AND VIBRATIONS	INTERCOM ENGINE TRACK, ETC.
	LOAD, CHANGE AND RE-LOAD COAX (7.62) MACHINE GUN; MONITOR GUN FOR AMMUNITION EXPENDITURE; RE-FILL AMMO BOX BETWEEN ENGAGEMENTS, IN MOVING AND STATIONARY TURRET	HIGH	VISUAL CUES TO AMMO QUANTITY AND RATE OF USE	TURRET PITCH, ROLL AND VIBRATION	MACHINE GUN FIRING
2 RESPOND TO WEAPON MALFUNCTIONS	RECOGNIZE MAIN GUN MALFUNCTIONS; APPLY IMMEDIATE ACTION, AS REQUIRED.	HIGH	BREECH AND FIRING MECHANISM	TURRET MOTION IN PITCH, ROLL, VIBRATIONS	INTERCOM; ENGINE TRACK, ETC.
	UNLOAD AND RE-LOAD MAIN GUN, AS REQUIRED, IN MOVING AND STATIONARY TURRET	HIGH	SEE 2.1	See 2.1	INTERCOM; ENGINE TRACK, ETC.
	RECOGNIZE SOUNDS ASSOCIATED WITH 7.62 MM MACHINE GUN STOPPAGES. APPLY IMMEDIATE ACTION IN CHANGING COAX GUN.	HIGH	MACHINE GUN	TURRET MOTION	SOUNDS OF FIRE AND STOPPAGES
	ASCERTAIN WHEN MAIN OR COAX GUNS CANNOT BE MADE AVAILABLE FOR FIRING	HIGH		TURRET MOTION	
3 SURVEILLANCE	SEARCH AREA FROM OPEN-HATCH AND CLOSED-HATCH POSITIONS (CIRECT VISION/PERISCOPE)	MEDIUM	MAIN OR TERRRAIN SURFACES AND FEATURES; SMOKE, FLASH, DUST, GLINT, REQUIREMENT VISIBLE THREATS.	TURRET MOTION	SOUND OF NEAR-MISS, SMALL ARMS, ARTILLARY
	RECOGNIZE SIGNS OF THREAT ACTIVITY IN SEARCHED AREA; REPORT SIGNS AND THREATS; ANTICIPATE MAON OR COAX GUN ENGAGEMENT; PREPARE TO SERVICE MAIN OR COAX GUNS.	MEDIUM			
4 MACHINE GUN FIRE	ENGAGE LOADER TARGETS AS DIRECTED BY TANK COMMANDER; OBSERVE TRACK AND BULLET STRIKE TO ASSURE EFFECTIVENESS OF FIRE SUPPORT TO CREW.	MEDIUM	TERRAIN AND AREA TARGETS (PERSONNEL AND/OR AREAS DEFINED BY TERRAIN AND/OR VEGETATIVE CULTURAL FEATURES	TURRET MOTION	MACHINE GUN FIRING
	PERFORM IMMEDIATE ACTION ON LEADER'S WEAPONS	MEDIUM	MACHINE FIRING	TURRET MOTION	

crew interaction training setting to learn to support the crew in loader engagements.

The loader is the key to rapid sustained fire; he is exposed to more physical stress than anyone else in the crew, and to more hazard from his work station equipment. Assuming complete training in his individual skills and responsibilities, he requires extensive training in integrating these skills within the total crew responsibility, in making the proper weapon and ammunition available as needed, and in sharing in the protection of the tank from battlefield threats.

Table 5-4 summarizes the loader's mission tasks and the associated training objectives. The table also rates the criticality of the tasks and indicates the visual, motion and aural cues necessary to support training.

5.4.4 Driver. The tank moves over the terrain to an objective or, in defensive missions, moves from one firing point to another, at the direction of the tank commander, but under the control of the driver. The driver keeps the tank concealed to the greatest extent possible, maintains the turret as stable as he can for effective target detection and engagement, and he keeps the tank moving over a wide variety of terrain and through and over a variety of obstacles. Even though the driver operates under the direction of the commander, he enhances the effectiveness and the survivability of the tank when he correctly anticipates the directions the commander would give, by analyzing what he knows, hears and sees at any given time. His effect on the mission is in relieving the commander of some of the responsibility of route selection and negotiation, and in reacting more quickly to situations demanding changes in routes or positions than would be possible with the intervention of the tank commander.

The driver not only selects and negotiates routes, but also maintains surveillance to detect threats and signs of threat activity. In addition, he observes during firing, when possible, to sense and adjust fire which the commander and gunner may not be able to see.

Effective driver training is extremely difficult to provide because of its demands on terrain facilities that are capable of supporting tactically oriented training exercises. The driver must know in detail the reaction of the tank to all kinds of terrain surfaces, features and obstacles. He must also know how to pick terrain which offers cover from likely threat areas, to minimize the vulnerability of the tank while maximizing its ability to detect and engage hostile forces. The driver needs training in terrain appreciation, route selection and negotiation and target acquisition. Some of this training can be provided in the Basic Armor Training Course for tank drivers, but

TABLE 5-4 M60A3 DRIVER TRAINING OBJECTIVES

TASK	TRAINING OBJECTIVES	CRITI-CALITY	CUE REQUIREMENTS: VISUAL	CUE REQUIREMENTS: MOTION	CUE REQUIREMENTS: AURAL
1 ANALYZE TERRAIN					
1.1 IDENTIFY CHECKPOINTS TO OBJECTIVE	RECOGNIZE TERRAIN, CULTURAL FEATURES DEFINED BY TC AND/OR TERRAIN MAP, WHICH DEFINE THE ROUTE TO THE OBJECTIVE	MEDIUM	MAJOR TERRAIN FEATURES; RIDGES, WOODLINES, OPEN SPACES, BUILDINGS, STREAMS, ROADS, INTERSECTIONS, HILLS, KNOLLS	NONE	INTERCOM/RADIO
1.2 IDENTIFY AREAS OF POSSIBLE THREAT ACTIVITY	RECOGNIZE TERRAIN AND CULTURAL FEATURES OFFERING COVER, CONCEALMENT, FIELDS OF FIRE AND APPROACHES TO POSSIBLE THREAT	MEDIUM	TREELINES, TREES, BRUSH, RIDGES, HILLS, KNOLLS, RA	NONE	INTERCOM/RADIO
1.3 IDENTIFY OBSTACLES AND POTENTIAL OBSTACLES TO TANK MOVEMENT	RECOGNIZE TERRAIN, CULTURAL AND TERRAIN SURFACE FEATURES WHICH COULD ACT AS OBSTACLES TO MOVEMENT	MEDIUM	SURFACE DETAILS AND OBSTACLES; WET, DRY TERRAIN, TREES, LOGS, ROCKS, SLOPES, DITCHES, RAVINES, OF VARIOUS SIZES AND DEGREES WITHIN AND BEYOND TANK CAPABILITY.	NONE	INTERCOM/RADIO
1.4 IDENTIFY AREAS OF COVER AND CONCEALMENT	RECOGNIZE FEATURES AFFORDING COVER AND CONCEALMENT ALONG THE AVAILABLE ROUTES	HIGH	TREELINES, BUSHES, STREAMBEDS, HILLS, KNOLLS; LIKELY THREAT AREAS IN THE DISTANCE, INCLUDING RIDGES, TREELINES AND TERRAIN IRREGULARITIES.	NONE	INTERCOME/RADIO
1.5 IDENTIFY POSSIBLE FIRING POSITIONS AND ROUTES	RECOGNIZE POSITIONS AFFORDING READY ACCESS COVER/CONCEALMENT, FIELDS OF FIRE AND EGRESS FOR STATIONARY FIRING; RECOGNIZE SURFACES AFFORDING STABILITY FOR STABILIZED FIRING	HIGH	TREELINES, BUSHES, STREAMBEDS, HILLS, KNOLLS, DIFFERENT SURFACE TEXTURES ALL WITHIN 200 METERS; GENERAL CUES TO POSSIBLE THREAT AREAS IN THE DISTANCE.	NONE	INTERCOM/RADIO
1.6 SELECT ROUTES AMONG NAVIGATIONAL CHECKPOINTS	SELECT ROUTES (UP TO 300 METERS) WHICH OPTIMIZE THE USE OF CONCEALMENT AND COVER, CAN BE NEGOTIATED AND AFFORD GOOD FIRING POSITIONS AND SURFACES; REQUIRE MINIMUM INTERACTION WITH TANK COMMANDER	HIGH	SEE 1.4; 1.5	NONE	INTERCOM/RADIO
2 NEGOTIATE TERRAIN AMONG CHECKPOINTS					
2.1 NEGOTIATE OBSTACLES AND SURFACES WITHIN THE CAPABILITY OF THE TANK	RECONGIZE TERRAIN SURFACES AND FEATURES, AND TERRAIN AND CULTURAL OBSTACLES WHICH CAN BE NEGOTIATED; GENERATE DRIVING CONTROLS TO NEGOTIATE THE VARIETY OF SURFACES AND CONDITIONS AVAILABLE TO THE M60A3.	HIGH	VARIOUS TERRAIN SURFACE CONDITIONS INCLUDING DRY, WET, SWAMP, SNOW, ICE AND VARIOUS SLOPES FOR DIRECT NEGOTIATION OR CROSSING; TREES (VARIOUS SIZES AND SPACINGS), DITCHES, STREAMS, WITHIN 200 METERS	PITCH, ROLL, VIBRATION	ENGINE, TRACK SOUNDS IN RELATION TO TERRAIN AND SURFACE TYPES. INTERCOM/RADIO
2.2 USE COVER AND CONCEALMENT WITH RESPECT TO THREAT AREA	OPERATE TANK TO MAKE MAXIMUM USE OF TERRAIN AND CULTURAL FEATURES FOR COVER AND CONCEALMENT WHILE MAINTAINING MAXIMUM SPEED OF MOVEMENT TOWARD THE OBJECTIVE	HIGH	SEE 2.1; 1.1 – 1.5	SEE 2.1	SEE 2.1
2.3 MAINTAIN TURRET STABILITY	SELECT PATH OF MOVEMENT AND COVERED TANK FOR MAXIMUM TURRET STABILITY FOR TARGET ACQUISITION AND ENGAGEMENT	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.4 SELECT AND NEGOTIATE SECURE/STABLE FIRING POSITIONS	RECOGNIZE AREAS PROVIDING COVER AND/OR CONCEALMENT FOR FIRING; RECOGNIZE SURFACES PROVIDING STABLE FIRING PLATFORM FOR FIRING ON THE MOVE; MOVE INTO AND OUT OF FIRING POSITIONS; MAINTAIN TANK LEVEL FOR STABILIZED MAIN GUN FIRING	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
[illegible] COAX, CAL. 50 FIR[illegible]	[illegible] COAX AND/OR CAL. 50 FIRING; MOVE TANK	MEDIUM	SEE 2.2; COAX AND CAL. 50	SEE 2.1	SEE 2.1; SOUNDS OF

OF THE TANK	CAN BE NEGOTIATED; GENERATE DRIVING CONTROLS TO NEGOTIATE THE VARIETY OF SURFACES AND CONDITIONS AVAILABLE TO THE M60A3.		SWAMP, SNOW, ICE AND VARIOUS SLOPES FOR DIRECT NEGOTIATION OR CROSSING; TREES (VARIOUS SIZES AND SPACINGS), DITCHES, STREAMS, WITHIN 200 METERS		TO TERRAIN AND SURFACE TYPES. INTERCOM/RADIO
2.2 USE COVER AND CONCEALMENT WITH RESPECT TO THREAT AREA	OPERATE TANK TO MAKE MAXIMUM USE OF TERRAIN AND CULTURAL FEATURES FOR COVER AND CONCEALMENT WHILE MAINTAINING MAXIMUM SPEED OF MOVEMENT TOWARD THE OBJECTIVE	HIGH	SEE 2.1; 1.1 — 1.5	SEE 2.1	SEE 2.1
2.3 MAINTAIN TURRET STABILITY	SELECT PATH OF MOVEMENT AND COVERED TANK FOR MAXIMUM TURRET STABILITY FOR TARGET ACQUISITION AND ENGAGEMENT	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.4 SELECT AND NEGOTIATE SECURE/STABLE FIRING POSITIONS	RECOGNIZE AREAS PROVIDING COVER AND/OR CONCEALMENT FOR FIRING; RECOGNIZE SURFACES PROVIDING STABLE FIRING PLATFORM FOR FIRING ON THE MOVE; MOVE INTO AND OUT OF FIRING POSITIONS; MAINTAIN TANK LEVEL FOR STABILIZED MAIN GUN FIRING	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.5 OPTIMIZE COAX, CAL. 50 FIRING PATTERNS	SENSE COAX AND/OR CAL. 50 FIRING; MOVE TANK TO OPTIMIZE WEAPON AREAS OF COVERAGE WITH MINIMUM TC/GUNNER TRACKING OF TARGET AREA.	MEDIUM	SEE 2.2; COAX AND CAL. 50 TRACER BURNOUT RANGES	SEE 2.1	SEE 2.1; SOUNDS OF COAX, CAL. 50 FIRING; SOUNDS OF TURRET SLEW, CUPOLA ROTATION
3 ACQUIRE TARTETS					
3.1 ANTICIPATE POSSIBLE THREAT LOCATIONS	RECOGNIZE TERRAIN AND CULTURAL FEATURES AFFORDING COVER FOR POSSIBLE THREATS; DISCRIMINATE AMONG TERRAIN SURFACES AND OBSTACLES WITH RESPECT TO SUPPORT OF THREAT CONCEALMENT AND MOVEMENT	MEDIUM	SEE 1.2	NONE	INTERCOM/RADIO
3.2 RECOGNIZE THREAT ACTIVITY AND THREAT ELEMENTS	RECOGNIZE SIGNS OF THREAT ACTIVITY; DISCRIMINATE AMONG THREAT TYPES	MEDIUM	SEE 1.2; SMOKE, DUST, MOVEMENT OF FOLIAGE, MOVEMENT OF PARTIALLY CONCEALED ELEMENTS; GLINT, FLASH, TRACER, MISSILE BODIES	NONE	INTERCOM/RADIO
3.3 REACT TO THREAT WEAPON LAUNCH	RECOGNIZE THREAT WEAPON FIRING; RECOGNIZE DIRECTION OF FIRING; ALERT CREW, TAKE EVASIVE ACTION AS APPROPRIATE; DISCRIMINATE WEAPONS HAVING VARIOUS LEVELS OF SIGNIFICANCE	HIGH	SMOKE, DUST, FLASH, TRACER, MISSILE BODY, WEAPON IMPACT	PITCH, ROLL, VIRATION	INTERCOM/RADIO; SOUNDS OF ENGINE, TRACK OVER TERRAIN
3.4 SENSE WEAPON EFFECTS	RECOGNIZE EFFECTS OF MAIN GUN, COAX, CAL. 50 AND LOADER'S WEAPON; SENSE FALL OF SHOT, PROVIDE ADJUSTMENT INFORMATION TO CREW; MAINTAIN NIGHT VISION DURING FIRING TO THE EXTENT POSSIBLE	HIGH	SMOKE, FLASH, DUST (OBSERVATION), TRACER, HITS ON SOFT, HARD TARGETS, SHORT ROUNDS IN DUSTY AND WET TERRAIN; BLACK, WHITE IMPACT SMOKE; ORANGE FLASH ON HARD TARGET HITS; WHITE PHOSPHOROUS SMOKE AND PARTICLES	PITCH, ROLL, VIBRATION ASSOCIATED WITH MOVEMENT AND WITH MAIN GUN	MAIN GUN, COAX, CAL. 50 SOUNDS
4 CONTROL TANK IN FORMATION					
4.1 CONTROL TANK IN ROAD FORMATION	RECOGNIZE RELATIVE MOTION WITH TANK AHEAD; CONTROL SPEED TO MAINTAIN PRESCRIBED INTERVAL; SENSE MOTION OF LEAD TANK AND OWN TANK IN RELATION TO ROAD SURFACE TEXTURE AND ROADSIDE OBJECTS	LOW	TANK SILHOUETTE AND DETAIL; INCLUDING TRACK, TAILLIGHT ASSEMBLIES; TURRET AND STORAGE RACKS; LIGHTED TAIL LIGHTS (NIGHT); ROAD SURFACE AND OBJECTS ALONG ROAD	PITCH, ROLL, VIBRATION (TANK MOVEMENT AND VARIOUS ROAD SURFACES	ENGINE, TRACK, SOUNDS, VARYING WITH TERRAIN SURFACE AND SPEED
4.2 CONTROL TANK IN COMBAT FORMATION	RECOGNIZE POSITION, SPEED OF ADJACENT TANK; PREDICT SPEED AND PATH OF ADJACENT TANK FROM TERRAIN CONFIGURATION; MAINTAIN REQUIRED RELATIVE POSITION AND SPEED.	MEDIUM	TANK SILHOUETTE AND DETAIL TERRAIN FEATURES AND SURFACES	PITCH, ROLL AND VIBRATION	ENGINE, TRACK, SOUNDS

17

much will have to be provided in other settings. Driver training in a crew interaction simulator must concentrate on giving the driver practice in making the kinds of decisions he would make in combat, but it would be uneconomical in hardware and software, and in the training of the rest of the crew, to train him to make the fine discriminations required in supporting those decisions. The full crew interaction training environment should permit each member of the crew, including the driver, to make the decisions peculiar to his task, and to practice anticipating the performance of the rest of the crew. It should also permit each member of the crew to practice dealing with his own decisions, and with those of the rest of the crew, in the best way possible, in a tactical environment.

5.4.4.1 Terrain Analysis. The driver drives at the direction of the tank commander, generally, and must be able to recognize terrain features used by the commander in giving guidance in route selection and negotiation, in moving toward the tank's objective. The tank commander will point out areas of possible threat activity so the driver can keep the tank concealed from them and so that he can search those areas more thoroughly for threats or signs of threat activity. The driver and the tank commander also search for obstacles which could stop or slow the tank, with the driver learning to differentiate between those which could be problems and those which are within the capability of the tank.

Throughout a tank mission, the driver constantly searches for advantageous firing positions, and for good routes into and out of those positions. A good firing position keeps as much of the tank concealed as possible, is near to the primary route, is not close to any prominent feature which could be used by the enemy as an aiming point, is readily accessible with minimum maneuvering and can be exited by a covered or concealed route. The driver must also learn to recognize smooth surfaces which can be used to stabilize the tank while firing on the move. The driver's choice of a given route at a given time depends on his ability to relate the characteristics of the terrain to the requirements of the mission at that time, and to his perception of the tactical situation. Opportunities to relate terrain characteristics to tactics in selecting and negotiating a route are rare, but require extensive practice on the part of the driver, and on the part of the rest of the crew in responding to driver choices relating to the terrain and its utilization.

5.4.4.2 Terrain Negotiation. The M60A3 tank can negotiate most of the terrain it would encounter in the central European area, but each terrain type and terrain surface will have a specific effect on the speed, maneuverability and agility of the tank. The driver must learn to move the tank over the routes available, optimizing cover, concealment, speed, stability, maneuverability or agility, as required at any given time. At the same

time, the driver must move over the terrain in such a way as to minimize, where possible, the physical stresses on the tank itself so that it can complete its mission. In addition, the driver must be aware of the effects of the terrain on the crew, especially when the gunner and commander are attempting to detect and engage threats. Each situation, and each terrain feature and surface require a different response on the part of the driver.

One of the driver's most difficult tasks in route negotiation is in recognizing terrain, vegetative, and cultural features which afford him cover and concealment as he moves toward the objective. First, of course, the driver must recognize either the objective or a checkpoint along the route, which he must pass. Second, he must recognize areas where threats could be concealed, along his potential route. Finally, he must visualize his appearance from the threat area as he moves among features which might afford cover or concealment. The driver must be constantly aware of the position of the turret and the rear of the hull, so that he can discriminate among positions which hide him, but reveal the turret and those which hide significant portions of the tank.

The driver has a profound effect on the performance of the gunner, the commander, and the loader. He attempts to keep the vibration level in the turret as low as possible, particularly when the crew uses powered optics for target detection, acquisition, and engagement. During stabilized firing, he moves the tank at as constant a rate as possible over the smoothest ground available, to minimize gunner and commander tracking problems, and to help the loader to load rapidly and safely. The driver can also strongly influence the effectiveness of machine gun fire; the coax and .50 caliber "Z" patterns depend on the smooth, steady motion of the tank to provide target coverage in the diagonal bar of the "Z"; erratic driving can greatly reduce machine gun cover of area targets and, thus, the security of the tank.

5.4.4.3 Target Acquisition. The gunner's position in the hull places him at a disadvantage in acquiring targets at long range, but variations in the terrain can frequently place him in a position to detect threats and threat indications at ranges as long as those viewed by the turret crew, with the naked eye. Since the driver is more concerned with the terrain to his immediate front than the crew in the turret, he is in a good position to acquire targets at close range, which the rest of the crew might miss. When the driver sees a threat, or an indication of threat activity, he alerts the crew, describing the type of event he sees, its approximate range and its location. Ordinarily, the tank commander examines the area designated by the driver (or any other crewmember) and decides whether a threat is involved, how important it is and whether to evade or engage it, issuing steering and/or fire commands as appropriate.

Many threats sensed or detected by the driver will be at relatively close range; in many of these cases, the driver will have to learn to evade them as quickly as possible, while he alerts the crew. Anti-tank guided missiles can be seen in flight; when the driver sees the missile launched, he can sometimes evade it by dropping behind a knoll, or by changing his path quickly enough to exceed the missile's turning capability. Training in making the decisions imposed on the driver by threats and apparent threats is difficult to provide in real-world training settings, but is crucial to the success of the tank on the battlefield. The position of the driver beneath the main gun gives him some advantage in sensing main gun effects; in many instances, his position out of the primary obscuration caused by firing the main gun permits him to sense and adjust rounds lost by the crew in the turret. In each engagement in which he can see the target area, the driver reports his sensing to permit rapid adjustment of fire and timely target effect. Drivers receive some training in this process, but rarely in anything like the stress and decision-making environment in which they must operate in tank combat.

5.4.4.4 Formation Control. Tanks always operate in elements of two or more, either in combat, or in road marches. In both situations, they provide mutual support in surveillance, target acquisition and engagement. In combat, they frequently operate with mutual visual contact, with relative position controlled either by direction of the tank commanders or by the drivers. When they move in contact with the enemy, one element moves toward the objective, while the other covers its movement from a covered position. Movement is by alternate bounds, so that one element is always prepared to fire at any threat to the moving element, to protect it while it is exposed.

The drivers of tanks in contact with the enemy must be alert not only to the positions of threats and potential threats, but to the position and movement of adjacent friendly tanks as well, controlling speed and direction to maintain mutual contact, cover and mutual support. When the driver can see the terrain in the vicinity of the other tank, and the likely positions of hostile elements, he can predict and react quickly to changes in the speed and path of the other tank.

In route formations, the driver keeps his tank at a prescribed interval from the tank ahead. The interval is established by the unit commander, to minimize the vulnerability of the unit to air or artillery strikes or ambushes, and to maintain visual contact among tanks. The driver maintains his interval by noting relative motion among the tanks ahead, his own tank, and features along the route ahead. He also notes changes in the legibility of features on the tank ahead. At night, he controls his distance from the tank ahead by noting the number of tail light elements visible at a given time. Driving in fog and

smoke is especially difficult because of variable effects on detail legibility, and on the visibility of scene details along the route.

In general, drivers have good opportunities, especially in unit training exercises, to learn the skills involved in driving in route formation. Combat driving skills are complex and difficult, and are rarely able to be practiced in real-world exercises because of severe constraints on the use of terrain. In addition, it is not feasible for unit training exercises to involve realistic threats in the training of crews.

Table 5-5 summarizes the driver's mission tasks and the associated training objectives. The table also rates the criticality of the tasks and indicates the visual, motion and aural cues required to support training.

5.4.5 Crew Training Requirements Summary. The crew of the M60A3 tank is being trained well in BAT, in the individual skills required to operate the tank and its systems in non-combat environments. New driving and gunnery courses are providing drivers and gunners with excellent training in dealing with a variety of relevant terrain and engagement conditions, but few opportunities exist for training the entire crew as an articulated, integrated team.

Full crew training requires, more than anything, opportunities for the crew to interact realistically with widely-variable terrain and tactical environments. Terrain characteristics impose stresses on the entire crew, and a need for choices on the part of the tank commander and the driver. Tactical conditions, including threats and friendly elements on and around the battlefield also impose requirements for choices on the crew, and both terrain and tactical elements change as the crew implements its choices of routes, speeds, maneuvers and engagements.

The tactical situations in which the M60A3 will be used will place a great deal of stress on the crew, and will demand accurate individual and crew performance within very short time periods, which allow for little or no trial-and-error behavior. Individual driving and gunnery skills will suffer greatly in the stress of combat, unless crews are able in training, to develop automatic responses to the range of combat situations in which the M60A3 will be employed. Full crew interaction training must provide opportunities for individuals to learn to react skillfully to terrain and tactical conditions and, equally important, to the unique reactions of other members of the crew. Tables 4-2 through 4-5 and Tables 5-2 through 5-5 are illustrations of the intimate interactions typical of M60A3 combat engagements; they indicate the complexity of the crew's responsibilities and the manner in which rapid, accurate crew interactions must take place for effective employment of the tank.

TABLE 5-5 M60A3 DRIVER TRAINING OBJECTIVES

TASK	TRAINING OBJECTIVES	CRITICALITY	CUE REQUIREMENTS: VISUAL	CUE REQUIREMENTS: MOTION	CUE REQUIREMENTS: AURAL
1 ANALYZE TERRAIN					
1.1 IDENTIFY CHECKPOINTS TO OBJECTIVE	RECOGNIZE TERRAIN, CULTURAL FEATURES DEFINED BY TC AND/OR TERRAIN MAP, WHICH DEFINE THE ROUTE TO THE OBJECTIVE	MEDIUM	MAJOR TERRAIN FEATURES; RIDGES, WOODLINES, OPEN SPACES, BUILDINGS, STREAMS, ROADS, INTERSECTIONS, HILLS, KNOLLS	NONE	INTERCOM/RADIO
1.2 IDENTIFY AREAS OF POSSIBLE THREAT ACTIVITY	RECOGNIZE TERRAIN AND CULTURAL FEATURES OFFERING COVER, CONCEALMENT, FIELDS OF FIRE AND APPROACHES TO POSSIBLE THREAT	MEDIUM	TREELINES, TREES, BRUSH, RIDGES, HILLS, KNOLLS, RA	NONE	INTERCOM/RADIO
1.3 IDENTIFY OBSTACLES AND POTENTIAL OBSTACLES TO TANK MOVEMENT	RECOGNIZE TERRAIN, CULTURAL AND TERRAIN SURFACE FEATURES WHICH COULD ACT AS OBSTACLES TO MOVEMENT	MEDIUM	SURFACE DETAILS AND OBSTACLES; WET, DRY TERRAIN, TREES, LOGS, ROCKS, SLOPES, DITCHES, RAVINES, OF VARIOUS SIZES AND DEGREES WITHIN AND BEYOND TANK CAPABILITY.	NONE	INTERCOM/RADIO
1.4 IDENTIFY AREAS OF COVER AND CONCEALMENT	RECOGNIZE FEATURES AFFORDING COVER AND CONCEALMENT ALONG THE AVAILABLE ROUTES	HIGH	TREELINES, BUSHES, STREAMBEDS, HILLS, KNOLLS; LIKELY THREAT AREAS IN THE DISTANCE, INCLUDING RIDGES, TREELINES AND TERRAIN IRREGULARITIES.	NONE	INTERCOME/RADIO
1.5 IDENTIFY POSSIBLE FIRING POSITIONS AND ROUTES	RECOGNIZE POSITIONS AFFORDING READY ACCESS COVER/CONCEALMENT, FIELDS OF FIRE AND EGRESS FOR STATIONARY FIRING; RECOGNIZE SURFACES AFFORDING STABILITY FOR STABILIZED FIRING	HIGH	TREELINES, BUSHES, STREAMBEDS, HILLS, KNOLLS, DIFFERENT SURFACE TEXTURES ALL WITHIN 200 METERS; GENERAL CUES TO POSSIBLE THREAT AREAS IN THE DISTANCE.	NONE	INTERCOM/RADIO
1.6 SELECT ROUTES AMONG NAVIGATIONAL CHECKPOINTS	SELECT ROUTES (UP TO 300 METERS) WHICH OPTIMIZE THE USE OF CONCEALMENT AND COVER, CAN BE NEGOTIATED AND AFFORD GOOD FIRING POSITIONS AND SURFACES; REQUIRE MINIMUM INTERACTION WITH TANK COMMANDER	HIGH	SEE 1.4; 1.5	NONE	INTERCOM/RADIO
2 NEGOTIATE TERRAIN AMONG CHECKPOINTS					
2.1 NEGOTIATE OBSTACLES AND SURFACES WITHIN THE CAPABILITY OF THE TANK	RECONGIZE TERRAIN SURFACES AND FEATURES, AND TERRAIN AND CULTURAL OBSTACLES WHICH CAN BE NEGOTIATED; GENERATE DRIVING CONTROLS TO NEGOTIATE THE VARIETY OF SURFACES AND CONDITIONS AVAILABLE TO THE M60A3.	HIGH	VARIOUS TERRAIN SURFACE CONDITIONS INCLUDING DRY, WET, SWAMP, SNOW, ICE AND VARIOUS SLOPES FOR DIRECT NEGOTIATION OR CROSSING; TREES (VARIOUS SIZES AND SPACINGS), DITCHES, STREAMS, WITHIN 200 METERS	PITCH, ROLL, VIBRATION	ENGINE, TRACK SOUNDS IN RELATION TO TERRAIN AND SURFACE TYPES. INTERCOM/RADIO
2.2 USE COVER AND CONCEALMENT WITH RESPECT TO THREAT AREA	OPERATE TANK TO MAKE MAXIMUM USE OF TERRAIN AND CULTURAL FEATURES FOR COVER AND CONCEALMENT WHILE MAINTAINING MAXIMUM SPEED OF MOVEMENT TOWARD THE OBJECTIVE	HIGH	SEE 2.1; 1.1 – 1.5	SEE 2.1	SEE 2.1
2.3 MAINTAIN TURRET STABILITY	SELECT PATH OF MOVEMENT AND COVERED TANK FOR MAXIMUM TURRET STABILITY FOR TARGET ACQUISITION AND ENGAGEMENT	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.1 SELECT AND NEGOTIATE SECURE/STABLE FIRING POSITIONS	RECOGNIZE AREAS PROVIDING COVER AND/OR CONCEALMENT FOR FIRING; RECOGNIZE SURFACES PROVIDING STABLE FIRING PLATFORM FOR FIRING ON THE MOVE; MOVE INTO AND OUT OF FIRING [illegible]	HIGH	SEE 2.2	SEE 2.1	SEE 2.1

OF THE TANK	CAN BE NEGOTIATED; GENERATE DRIVING CONTROLS TO NEGOTIATE THE VARIETY OF SURFACES AND CONDITIONS AVAILABLE TO THE M60A3.		SWAMP, SNOW, ICE AND VARIOUS SLOPES FOR DIRECT NEGOTIATION OR CROSSING; TREES (VARIOUS SIZES AND SPACINGS), DITCHES, STREAMS, WITHIN 200 METERS		TO TERRAIN AND SURFACE TYPES. INTERCOM/RADIO
2.2 USE COVER AND CONCEALMENT WITH RESPECT TO THREAT AREA	OPERATE TANK TO MAKE MAXIMUM USE OF TERRAIN AND CULTURAL FEATURES FOR COVER AND CONCEALMENT WHILE MAINTAINING MAXIMUM SPEED OF MOVEMENT TOWARD THE OBJECTIVE	HIGH	SEE 2.1; 1.1 — 1.5	SEE 2.1	SEE 2.1
2.3 MAINTAIN TURRET STABILITY	SELECT PATH OF MOVEMENT AND COVERED TANK FOR MAXIMUM TURRET STABILITY FOR TARGET ACQUISITION AND ENGAGEMENT	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.4 SELECT AND NEGOTIATE SECURE/STABLE FIRING POSITIONS	RECOGNIZE AREAS PROVIDING COVER AND/OR CONCEALMENT FOR FIRING; RECOGNIZE SURFACES PROVIDING STABLE FIRING PLATFORM FOR FIRING ON THE MOVE; MOVE INTO AND OUT OF FIRING POSITIONS; MAINTAIN TANK LEVEL FOR STABILIZED MAIN GUN FIRING	HIGH	SEE 2.2	SEE 2.1	SEE 2.1
2.5 OPTIMIZE COAX, CAL. 50 FIRING PATTERNS	SENSE COAX AND/OR CAL. 50 FIRING; MOVE TANK TO OPTIMIZE WEAPON AREAS OF COVERAGE WITH MINIMUM TC/GUNNER TRACKING OF TARGET AREA.	MEDIUM	SEE 2.2; COAX AND CAL. 50 TRACER BURNOUT RANGES	SEE 2.1	SEE 2.1; SOUNDS OF COAX, CAL. 50 FIRING; SOUNDS OF TURRET SLEW, CUPOLA ROTATION
3 ACQUIRE TARTETS					
3.1 ANTICIPATE POSSIBLE THREAT LOCATIONS	RECOGNIZE TERRAIN AND CULTURAL FEATURES AFFORDING COVER FOR POSSIBLE THREATS; DISCRIMINATE AMONG TERRAIN SURFACES AND OBSTACLES WITH RESPECT TO SUPPORT OF THREAT CONCEALMENT AND MOVEMENT	MEDIUM	SEE 1.2	NONE	INTERCOM/RADIO
3.2 RECOGNIZE THREAT ACTIVITY AND THREAT ELEMENTS	RECOGNIZE SIGNS OF THREAT ACTIVITY; DISCRIMINATE AMONG THREAT TYPES	MEDIUM	SEE 1.2; SMOKE, DUST, MOVEMENT OF FOLIAGE, MOVEMENT OF PARTIALLY CONCEALED ELEMENTS; GLINT, FLASH, TRACER, MISSILE BODIES	NONE	INTERCOM/RADIO
3.3 REACT TO THREAT WEAPON LAUNCH	RECOGNIZE THREAT WEAPON FIRING; RECOGNIZE DIRECTION OF FIRING; ALERT CREW, TAKE EVASIVE ACTION AS APPROPRIATE; DISCRIMINATE WEAPONS HAVING VARIOUS LEVELS OF SIGNIFICANCE	HIGH	SMOKE, DUST, FLASH, TRACER, MISSILE BODY, WEAPON IMPACT	PITCH, ROLL, VIRATION	INTERCOM/RADIO; SOUNDS OF ENGINE, TRACK OVER TERRAIN
3.4 SENSE WEAPON EFFECTS	RECOGNIZE EFFECTS OF MAIN GUN, COAX, CAL. 50 AND LOADER'S WEAPON; SENSE FALL OF SHOT, PROVIDE ADJUSTMENT INFORMATION TO CREW; MAINTAIN NIGHT VISION DURING FIRING TO THE EXTENT POSSIBLE	HIGH	SMOKE, FLASH, DUST (OBSERVATION), TRACER, HITS ON SOFT, HARD TARGETS, SHORT ROUNDS IN DUSTY AND WET TERRAIN; BLACK, WHITE IMPACT SMOKE; ORANGE FLASH ON HARD TARGET HITS; WHITE PHOSPHOROUS SMOKE AND PARTICLES	PITCH, ROLL, VIBRATION ASSOCIATED WITH MOVEMENT AND WITH MAIN GUN	MAIN GUN, COAX, CAL. 50 SOUNDS
4 CONTROL TANK IN FORMATION					
4.1 CONTROL TANK IN ROAD FORMATION	RECOGNIZE RELATIVE MOTION WITH TANK AHEAD; CONTROL SPEED TO MAINTAIN PRESCRIBED INTERVAL; SENSE MOTION OF LEAD TANK AND OWN TANK IN RELATION TO ROAD SURFACE TEXTURE AND ROADSIDE OBJECTS	LOW	TANK SILHOUETTE AND DETAIL; INCLUDING TRACK, TAILLIGHT ASSEMBLIES; TURRET AND STORAGE RACKS; LIGHTED TAIL LIGHTS (NIGHT); ROAD SURFACE AND OBJECTS ALONG ROAD	PITCH, ROLL, VIBRATION (TANK MOVEMENT AND VARIOUS ROAD SURFACES	ENGINE, TRACK, SOUNDS, VARYING WITH TERRAIN SURFACE AND SPEED
4.2 CONTROL TANK IN COMBAT FORMATION	RECOGNIZE POSITION, SPEED OF ADJACENT TANK; PREDICT SPEED AND PATH OF ADJACENT TANK FROM TERRAIN CONFIGURATION; MAINTAIN REQUIRED RELATIVE POSITION AND SPEED.	MEDIUM	TANK SILHOUETTE AND DETAIL TERRAIN FEATURES AND SURFACES	PITCH, ROLL AND VIBRATION	ENGINE, TRACK, SOUNDS

Many engagements will require each member of the crew to perform his individual task within a total crew function lasting no more than 5 to 8 seconds from the alert to the strike of the first round. This means that the driver will have to find and move into a route or a position, selected for its view of the threat and for its cover from threat observation, and for its minimal effect on turret stability. At the same time, the loader will locate, unlock and load the round designated by the commander while the gunner makes the proper settings on his computer and gun controls and slews the sight into the target. The commander initiates the engagement and monitors the crew's performance, simultaneously searching for other threats and for significant changes in the tactical situation. Each member of the crew does his job automatically, responding to sometimes subtle variations in terrain, threats, threat deployments, weapon effects, visibility, commands and commentary on the part of the tank commander and other friendly elements. The essence of crew interaction training is in providing crews with practice in discriminating among different tactical situations, and in dealing with them, as a crew, under some of the physical, psychological,and time stresses associated with tank combat.

5.5 Tactical Information Requirements for Training

Tank crew interaction skills are developed through practice in the interpretation and utilization of information defining crew tasks and task conditions, in circumstances in which tactical elements and events are represented. Crews training in the Full Crew Interaction Simulator will have become skilled in the operation of the tank and its systems. They will have learned to respond to information inherent in the operation of the tank, and in the stylized environments encountered on the driving and gunnery ranges. Much of this same information will be available in the FCIS, but in addition, tactical information will be provided. This will permit crews to develop skill in integrating individual performances, and in keying those performances to events which are both complex and essentially unpredictable. The degree of skill capable of being developed in the FCIS setting will be a function, in large part, of the complexity of the tactical information available.

Six kinds of tactically-relevant information is required for effective training in crew interaction skills.

5.5.1 Terrain. The driver and the tank commander have the most crucial and detailed interest in the tactical interpretation of terrain-related information. The loader and the gunner, however, also have responsibilities in the observation and interpretation of terrain characteristics. Each member of the crew, at some time in a mission, observes the terrain and attempts to obtain information relating to the way in which he must perform his job.

For purposes of analysis, terrain is considered to include such features as hills, ridges, streams, ravines, ditches, and slopes. It also includes woodlines, trees and other vegetation, cultural objects such as walls, roads, buildings and bridges and surfaces including hard dirt, sand, swamp,mud, ice and snow.

The characteristics of the terrain tell the skilled crewmember three things: where he (and the threat) can and cannot move, where he (and the threat) can hide and what effects he (and the threat) will experience in moving over the terrain, in terms of speed, maneuverability, cover and concealment. The tank commander examines the terrain at as long a range as possible, to anticipate threat locations and to identify potential routes of movement which afford both the surface consistency and the cover required for rapid and secure maneuvering. He also examines the terrain at close range, to assist the driver in finding the route which will provide the least degradation in speed and maneuverability and the best cover from known or suspected threat locations.

The loader and the gunner also examine the terrain, to anticipate threat locations, and to assist the driver in picking the most effective route. The gunner uses his magnified periscope and, at night, his thermal sensor to examine terrain surfaces out of the view of the driver. The loader, when he is available, uses unaided vision to assist the driver in moving over and among surfaces and obstacles in the immediate vicinity of the tank, while he searches for threats concealed in the terrain and among the vegetative and cultural features in the area.

5.5.2 The Tank and Its Systems. The crew will have become familiar with the performance characteristics and failure modes of the tank and its systems in BAT, but will have had little experience with its performance in a combat-like environment. At times, the mission will require the driver to negotiate terrain which he would otherwise avoid. This will place stresses on the tank and on the crew which will help them all to become more capable of responding effectively in combat. It will also help them to anticipate the conditions which the tank can and cannot negotiate, without exposing a real tank to these stresses.

The tank's response to various slopes, surfaces and obstacles, and the response of track and suspension systems are important in providing essential experience in the marginal operations which combat missions could dictate.

5.5.3 Communications. The entire crew of the tank hears the messages transmitted by way of the intercom, and the messages received and transmitted over the tank radios. Each message contains some information of tactical significance, helping to form the basis on which each member of the crew performs his job. The location of threats and friendly elements being supported by the tank, and supporting it, the effects of friendly

and hostile fire and requests for specific movement and fire are all heard over the radio or the intercom. Even though some messages do not require or involve a specific response, each contributes to a context which may have impact on the way tasks are initiated and performed.

Crew interaction training requires the crew to learn to deal with specific communications problems in a tactical context, and to respond within the context of what is heard as related to what is expected and seen at any given time. Training scenarios must contain tactical messages which direct the tank in specific operations, and general messages providing background tactical information which could influence the crew's performance of its mission. These messages could represent messages to other elements in the unit, or communications with supporting air, artillery or infantry elements.

5.5.4 Threats. The function of the tank is to destroy threats to its movement, and threats to the units and elements the tank is supporting. Threats must be engaged with the appropriate weapons and tactics and they must be destroyed, generally, at the greatest ranges possible. Use of the wrong weapon could give the tank's position away without destroying the threat. Failure to destroy a threat at maximum range can greatly add to the vulnerability of the tank by simplifying the threat's engagement problem.

On the battlefield, the tank will frequently encounter more than one threat at a time, requiring the crew to react to the more lethal threat first or, when the situation demands, requiring the crew to avoid any engagement until conditions are more favorable. The crew must be exposed to multiple targets and to multiple target types, and to targets at various ranges, out to 3000 meters. Tanks, armored personnel carriers, personnel, high-performance aircraft and helicopters can be engaged by the M60A3, and each requires a different combination of weapons and tactics.

Since the purpose of the FCIS is to train crews to work together in a tactical context, it is important that they encounter multiple threats and threat types; the extent of target image detail required for target detection training cannot be justified, since this can be accomplished in other settings, especially for the gunner and the tank commander, who need it most. The function of threat images in the FCIS simulated visual scene is not to teach discrimination and recognition, but to permit the teaching of interactive responses to many kinds of tactical situations, of which specific threats are a part.

In central European combat environments, threats will frequently be detected as a result of some kind of threat activity, other than exposure to view. Smoke, flash, glint, dust and the movement of foliage or a shape concealed by foliage will cause the

crew to examine an area more carefully, either with magnified optics, or using reconnaissance by fire. Thus, threats must be represented by relatively indeterminate "effects" cues, including ricochets, tracer fire and explosions,as well as distinct threat shapes.

5.5.5 Weapon Effects. The effects of supporting weapons, threat weapons and the tank's own weapons furnish a great deal of information vital to the effective conduct of the tank mission. The effects of threat weapons, particularly at close range, can cause the tank to fire, to change its route or to look for a hiding place. They can also give away enemy positions, if the weapon impact can be related to weapon firing cues. The effects of friendly weapons can indicate the destruction of positions and elements which might otherwise threaten the tank, freeing it to use routes otherwise denied it, and to engage threats which would otherwise be evaded, or allocated to later engagement. The tank will frequently be required to adjust friendly fire. Weapon effects occurring in the vicinity of specific threats, or specific landmarks in the field of view can be adjusted into the target area by the crew, using the radio, telephone or other communication systems.

The effects of the tank's own weapons are extremely important, since they tell whether an engagement has been successful or not, and the nature of any aiming errors made in the engagement. Like friendly artillery effects, they provide the information needed in destroying the target quickly and economically.

Own gun tracers and round impacts are used in controlling and adjusting fire. The burnout of 7.62 and .50 caliber tracers is also useful in determining range to an area or target. Since many targets will be situated on uneven terrain, it is important that tracers and weapon impact effects correlate generally with the terrain. Weapon impacts must also correlate with the type of target struck. SABOT, HEP and HEAT rounds should produce a red flash and smoke when they hit a hard target such as a tank or a concrete emplacement, but should only throw up smoke, dust and dirt when hitting the ground.

The effects of weapons fired by tanks in the same unit are especially important, in supporting practice in fire-and-maneuver. When a target is engaged by adjacent tanks, the crew must observe the effect on the target before moving on in the mission.

5.5.6 Visibility Effects. The M60A3 is well-equipped to operate at night and in periods of limited visibility, using its image intensifier and thermal sighting systems. The crew needs extensive training in night operations because of the limitations in field of view imposed by the night viewing systems, and because the images they provide require training for their accurate interpretation. Both systems are monochromatic, eliminating some of the visual information normally available to

the crew. In addition, each has its own unique response characteristics which are unique with respect to normal daylight viewing. The thermal sighting system responds to reflected and emitted infra-red, rather than to reflected visible light, producing images in which contrasts and forms are confusing until the crew has had time to correlate them with the daylight images ordinarily observed.

The image intensifier intensifies low-level visible light rather than infra-red, and so produces images more closely approximating those the driver would see in daylight. The image-intensifier system exaggerates contrasts, requiring extensive training in reconciling the displayed image with the reality encountered in driving over the viewed area.

The tank's smoke grenades, smoke fired by hostile elements and by friendly artillery, and the smoke resulting from massed fire of any kind obscures the tank battlefield. This makes movement, target detection and navigation more difficult, and influences the way in which the crew interacts. Smoke drifts with the wind, and while it conceals the tank from normal view, it can readily be penetrated by infra-red viewers. As a result, the crew operating in smoke must constantly be prepared to respond to engagements by threats.

SECTION VI

6. FCIS-LM EXPERIMENTAL REQUIREMENTS

6.1 Simulation Experiments

Three classes of simulator design and utilization experiments have been defined through analysis of the training tasks and of the FCIS statement of work. Each class is significant in its implications for the design of the FCIS system and in its requirements for experimenter/instructor/operator station design.

6.1.1 Simulator Fidelity. Simulation can provide most, but not all, of the characteristics associated with specific training functions in tank operations. At the same time, simulators can provide capabilities which appear to have training value but which are unavailable in real world operations. For example, actual tank dynamics normally cannot be changed but can be changed in the simulator to enhance the possible effectiveness of the learning environment. Experiments can be conducted to evaluate the training merit of various degrees of simulation fidelity, to determine minimum fidelity and cost requirements for specific types and levels.

Five aspects of simulator fidelity can be subjected to experimentation in defining fidelity levels and modes appropriate to enhancing simulator training value. Each of these aspects has implications for the design of the experimenter/simulator interface; each involves experimenter awareness of the status and content of specific portions of the simulator computer program, and each involves requirements for experimenter control over specific portions of the program. These five aspects are:

1) Tank Dynamics

2) Motion

3) Visual Simulation

4) Aural Cues

5) Control Loading

6.1.1.1 Tank Dynamics. Equations of motion can be represented in a variety of ways. Some of these methods have implications for simulator cost, some have implications for the facilitation of training. Experiments will determine whether smoothed equations, requiring less programming and implementation effort, are as effective for training certain crew tasks as are more complete rigorous equations. Also, experimental evaluations can be made of the value of temporarily modifying certain tank dynamics in making specific teaching points.

6.1.1.2 Motion. Motion of the driver compartment and turret provide information on tank performance, which must be represented in simulators to assure transfer of training from simulator to tank. Since all of the motions experienced in the real world cannot be reproduced in the simulator, studies must determine the relevance of those cues which can be reproduced, and methods of representing cues which cannot be reproduced. Specific types of experiments, which can be accomplished in the FCIS facility include:

1) Number of degrees of motion freedom required to train specific maneuvers, e.g., rotation about the three axes seems to be more important than translation along the vertical and lateral axes.

2) Degree of motion system excursion, velocity and acceleration required, along and around the three tank axes.

3) Variation in methods of motion cue representation, e.g., proportional cues, spiking, onset and washout, and shaping.

4) Differences in motion requirements for driver versus turret crew training.

5) Perceptual and training interactions among motion and visual cues. What type and degree of correlation is required between cues to efficiently train given tasks.

6.1.1.3 Visual Simulation. Visual cues to tank training can be represented in simulation, but the current state of knowledge about the interactions of visual information and the learning and execution of crew tasks is relatively incomplete; experimentation is required to establish the minimum visual system complexity (number of edges, number of objects, dynamics) required to support learning of specific crew tasks to specific skill levels. The FCIS-LM should permit the conduct of training in all relevant operations under a variety of visual cues, configurations, and interactions with other simulator characteristics. The complexity of the scene and detectability of various cues (threats, round fired, etc.) could be varied to evaluate various adaptive training and testing methods.

6.1.1.4 Aural Cues. Friendly, threat, and own tank sounds are used by crews as indicators of control requirements and tank and systems status. Many aural cues are subtle and difficult to identify in the myriad of sounds audible to the crew and require extensive experience in their perception and interpretation. It should be possible to experiment with manipulation of available sounds, to determine means of enhancing relevant sound components for crew training. Engine and track noise, round hits and intercom are examples of sounds that might be artificially altered to affect training.

6.1.1.5 Control Loading. Forces acting on the tank are reflected in the control pressures required to drive the tank and operate its systems. Control forces form part of the complex of information available to the crew in developing skills in executing various procedures and engagements. Part of the learning process consists of the development of new ways of perceiving available data in the exercise of control over the tank and its systems. Frequently, deliberate enhancement of critical information can facilitate the rate of learning. Once detection is assured, the crew can learn how that information relates to the task to be learned. As learning progresses, enhanced information can be returned to its normal form. Since the simulator control loading system represents a source of tank and systems control information, experimentation will permit its manipulation in the enhancement of simulator training effectiveness.

6.1.2 Simulator Utilization. Many of the experiments to be performed with the FCIS system involve the definition of effective and efficient ways of incorporating simulation in the tank training program, rather than the evaluation of specific simulator designs and configurations. The first of two classes of utilization experiments, of the three discussed below, have little impact on the design of the experimental simulator facility, while the third class of experiment depends heavily on the provision of advanced control and display capabilities at the experimenter's station.

6.1.2.1 Simulator Substitution. Simulator training can reduce the amount of time required by the crew, to achieve a given level of proficiency. Simulator substitution for actual tank time is possible because the crew can learn many of the responses required in the simulator, and because the simulator can be used to achieve levels of proficiency in skills involving dangerous or expensive training in the tank, such as tactical driving, interacting with a complex threat force, and firing the main gun, .50 caliber or coax. Current knowledge concerning those characteristics of the tank environment which relate to learning, and knowledge of the best ways of representing these characteristics in ground simulation is incomplete. Manipulation of the visual, motion and dynamic characteristics of the simulator will permit a variety of experiments in the substitution of various simulator capabilities for tank time throughout the range of skills taught in the M60 training syllabus. Experimentation should involve training in selected tasks, and tactical situations, with a variety of simulator configurations (as previously described) and the evaluation of proficiency resulting from this simulator training as compared to proficiency achieved in similar training in the tank itself (where such training is possible at all).

6.1.2.2 Syllabus Integration. A number of experiments will be required in determining the best way to integrating simulator and tank training. In some tasks, for example, training may benefit most from exposure to the simulator first, with subsequent consolidation of tasks, learning in the tank. In others it may be more effective when introduced in the tank, with proficiency practice provided in elements in the simulator. Interactions can be expected in the optimum order of employment of simulator and tank, with differences in simulator configuration. In effect, experimentation in this area of concern should involve training using specific simulator configurations and characteristics. Comparisons may be made of the relative proficiency of crews trained in a variety of simulator configurations and in a variety of orders of training sessions between the simulator and the tank.

6.1.2.3 Instructor Position. Many simulators provide instructor monitoring capabilities from stations remote from the crew stations. Typically, they can also provide more data for monitoring than is available in the tank. On the other hand, the instructor at the crew station has a wealth of information available simply from having visual and physical contact with the crew and with his operating environment. Experiments should be able to evaluate in- and out-of-crew area instructor positions for their ability to interface with the crew and the training context. Experiments may also permit the development of optimum methods of facilitating instructor monitoring and control at both the crew station and remote positions.

6.1.3 Experimenter/Instructor Station Design. The instructor controls the presentation of training problems to the crew, demonstrates procedures and maneuvers, sets the conditions of practice, and monitors and guides crew practice in a variety of ways. Interface between the instructor and simulator is critical; it provides information needed to monitor and diagnose crew performance and provides information to the instructor on the status of the simulator and the status of his own control input. The instructor/simulator interface also provides control over the simulator and its programs. In effect, the instructor station is a major factor in determining the capability of the instructor to effectively monitor, guide and control training.

Simulator instructor station design, over the past few years, has attempted to organize the various interface requirements consistent with the needs and capabilities of the instructor, to provide needed information in the most useful form to permit direct, immediate control of relevant simulator events, and to minimize instructor workload and training requirements. A function of the FCIS facility, in general, and the instructor/experimenter station in particular, is to support experiments in the definition of instructor information and control requirements, and the development of effective means of fulfilling

these requirements. These requirements are derived from reviews of tank training techniques, classroom instruction, and in part-task trainers. In each of these areas, there are implications for the improvement of simulator training through experimentation that are significant in the design of the instructor/experimenter station.

6.1.3.1 Equipment at Crew Observer Stations. The positioning of observers at the crew stations suggests experimentation in defining optimum ways of using the data and ways of utilizing them, and in defining and designing additional capabilities which would enhance the instructor's capabilities. Design efforts in relation to a crew station IOS require flexibility in providing simulator control capabilities and in formatting data for display. They also require consideration of the influence of the crew station environment on the instructor's ability to integrate available information and to actuate available simulator controls.

6.1.3.2 Conventional Equipment Requirements. Experience with simulators indicates that effective training requires that the instructor have a variety of data available reflecting the performance of the simulated vehicle, the crew, and the systems used in the conduct of training. The instructor also needs controls to facilitate communication with the crew, modification of the simulated environment, and the recording of data for crew evaluation and debriefing. Experience indicates further, that all data and control requirements are not needed at one time, and that their traditional form is not necessarily optimized for the instructional tasks with which they are identified. The development of evaluation of improved methods of instructor display and control implementation require that these traditional components be present, to support training in tasks within the capability of the simulator, and to permit their comparison with other approaches. The provision of conventional IOS equipment is required to support experimental comparison of various advanced approaches with the traditional approaches represented by the conventional IOS components and configurations.

6.1.3.3 Advanced Instructional Equipment. A proper function of the FCIS is to support experimentation in the development of advanced methods of simulator training, and the development of effective, efficient, and economical simulator design. Control capability must be provided to support these functions. It must support the manipulation of simulator characteristics (such as visual or motion fidelity) expected to have significant training and cost implications; it must support experiments in the automation of a variety of instructional monitoring (automatic engagement sequence timing) evaluation and control functions (automatic training sequencing); and it must support experiments in the development of advanced methods of information processing and display for optimizing instructor participation.

In addition, it must also support real-time training in the tasks associated with the M60 tank syllabus, using a variety of experimental instructional techniques (such as adapting complexity and scheduling).

6.2 Experimental System Requirements

Each of the functions requiring experimentation in the research simulator system involve experimenter and instructor tasks which require specific capabilities for data display and simulator control. Each task was analyzed to define these requirements in sufficient detail to permit their allocation to experimenter/instructor stations consistent with the overall requirements of the system and with the relative importance of each potential experiment. Six major task areas were identified from an analysis of the functional requirements defined in the statement of work, and from an analysis of the instructional implications of the M60 tank syllabus.

6.2.1 Experiment Tasks. Three of the task categories analyzed are essential primarily to the experimental functions required. They involve displays and controls associated with the instructional system. They represent capabilities for the manipulation of the major simulator characteristics expected to have significant impact on simulator efficiency, effectiveness and cost, within the M60 tank training program. These tasks are covered in the following paragraphs.

6.2.1.1 Program Simulator Fidelity. A major function of the research simulator system is to evaluate the relative effectiveness of various simulator fidelity levels in the development of essential crew skills. In general, simulator cost increases with increases in fidelity. Experience and a limited amount of formal research indicates that lower fidelity is as effective as high fidelity in training some tasks, depending on the task level required and the circumstances under which training is given. At the same time, it is apparent that lower fidelity simulation may provide great training value, particularly during the early stages of training.

The simulator should permit experiments involving a variety of fidelity levels and modes, by providing a capability for access to the simulation programs stored in the system computer and by permitting changes to be made in the programs defining simulator fidelity. The experimenter should be able to modify the tank equations of motion, the characteristics of the visual simulation system, the characteristics of the motion systems, and the control loading system. The aural cue system will also be accessible through the computer program, permitting the experimenter to delete or enhance significant components of simulated tank and environment sounds.

6.2.1.2 Program Automated Instructional Features. Automated instruction promises to reduce requirements for instructors and instructor training. It also promises to facilitate the standardization of training and performance evaluation, diagnosis, scoring and guidance. The FCIS system will permit a variety of experiments to be performed in the development of methods of automated instruction, and in optimizing the role of the instructor and of the automated instructional program in the simulator system. Tasks analyzed in this area are concerned with pre-programming automated training sequences, demonstrations, recording functions, modifications in task difficulty, crew performance measurement, and feedback to the crew and to the instructor.

6.2.1.3 Exercise Manual Simulator Control. Experiments in automated instructional methods will require pre-programming of functions which would ordinarily be performed on-line, in real time by the instructor. Current data on the pre-programming and automation of instructional functions are sparse, making it necessary to provide for experimentation in various modes of integrating automated and manual instructional. For this reason, experiments in which the instructor is given manual control over critical simulator events during the conduct of automated exercises to facilitate the development of optimal instructor utilization concepts, should be possible. The instructor should be able to manually insert malfunctions that have not been incorporated in an automatic program, and to inhibit malfunctions which have. To facilitate the preparation of programs for experimentation, the experimenter will be able to record and play back performance demonstrations and modify simulator characteristics expected to have significance for training.

6.2.2 Training Tasks. In most cases, experiments will consist of the programming of a selected configuration which is expected to influence training, or pre-programming some significant set of instructional functions, followed by the administration of training to experimental and control groups in some relevant task or subtask. Training may take place using an instructor station at the crew station or at a remote location, with both having capabilities for flexible data formatting and for integrating manual and automated instructional functions. The choice of instruction station for a given experiment will depend on the nature of the experiment. Experiments designed to optimize the performance of the instructor in direct contact with the crew will employ the crew station instructor station; those designed to compare alternate instructor station design features, will employ the remote station.

The two types of instructional techniques employed will be consistent with methods employed in tank training. First, the instructor will employ the simulator to demonstrate procedures, tasks, and maneuvers to the crew. Second, he will monitor,

evaluate, and guide crew performance of procedures, tasks, and engagements. The methods used in applying these techniques will vary, depending on the simulator capability under evaluation at a given time. Two classes of instructional tasks have been analyzed for their implications for the design of the FCIS system and its experimenter/instructor stations.

6.2.2.1 Train Subject(s) from Crew Station Positions. The FCIS provides an instructor position at the crew station. This instruction station, in direct contact with the crew, provides a unique and valuable teaching environment which is likely to be further enhanced by the addition of appropriate simulator controls and displays. Experiments will be performed in the development of teaching techniques peculiar to the crew station enviornment, and in the selection, organization, and utilization of display and control capabilities available. It is also likely that experiments will be used to develop teaching techniques and instructor interfaces useful in tank training.

6.2.2.1.1 Demonstrate Syllabus Tasks. The instructor's position should be designed to facilitate the demonstration of procedures and maneuvers. With the addition of interface equipment available to the simulator, more extensive demonstrations will be possible in the simulator than in the tank, particularly in the area of high density tactics.

6.2.2.1.2 Monitor Subject(s) Performance. Crew Station instructor positioning permits a mode of crew monitoring not available in most tank training. It provides a unique opportunity for the instructor to make subjective evaluations and diagnoses of performance and crew learning problems. This basic capability, together with computer interface capability, will support a variety of experiments on crew monitoring and guidance applicable to both simulator and tank.

6.2.2.2 Train Subject(s) from Remote Position. The research simulator should contain a sophisticated, highly flexible capability for programming and administering automated instruction, and manipulation of the interface among the instructor, crew, and the simulator computer program. Training could be conducted from this station in automatic and semi-automatic modes. Experiments should also be conducted from this station in the development of advanced display and control modes, to improve the quality of the instructor/simulator interface. Typically, performance displays configured for one instructional function may be inappropriate to others; the advanced capability would permit a variety of display combinations and formats to be evaluated for their applicability to specific training problems. It would also permit a variety of control modes, from manual through fully automatic, to be evaluated for their contribution to training effectiveness and efficiency.

6.2.2.2.1 Demonstrate Syllabus Tasks. While formal demonstrations of tasks are best performed in the simulator crew station itself, demonstrations from an external simulator station could be crucial, particularly where the instructor needs to make a point extemporaneously, by temporarily overriding the crew's control inputs. While the demonstration of complete tasks or maneuvers from an external station appears impractical for most syllabus tasks, a need exists for experimenting with instructor use of momentary inputs to the crews controls to demonstrate a point. For example; many tasks are performed incorrectly because of poor timing. The effectiveness of the instructor may be enhanced by judicious use of this limited demonstration capability which may be evaluated at the instructor/experimenter's station.

6.2.2.2.2 Monitor Subject Performance. A large part of simulator instruction involves observation of crew performance by whatever means are available, evaluating performance against a set of objective or subjective criteria, diagnosing performance and learning problems, and providing guidance in the form of suggestions, demonstrations, or modifications of the conditions of practice. One problem in simulator instructor station design has been identifying and implementing optimum methods of displaying information required by the instructor for effective performance monitoring and diagnosis. Also, once an optimum approach is defined for monitoring one type of task, it appears inappropriate for others. The problem has been minimal in instrument flight trainers due to the similarity of tasks being monitored. With visual tank simulation, the problem becomes critical in facilitating instructor monitoring of instrument as well as contact tasks. Instructional provisions should permit the development of monitoring formats applicable to specific tasks, using the display flexibility provided by any of several available systems.

Another performance monitoring problem has been the evaluation of performance. The complexity of many tasks tax the instructor's ability to integrate available data and make essential comparisons of real-time performance with the standards established for the task. Experiments will also be possible to evaluate methods of displaying criteria for real-time comparison, and to identify remedial actions required to meet these standards.

6.2.3 Control and Display Requirements. Table 6-1 outlines the control capability and display information necessary to conduct the type of training experimentation described in this section.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
1. Direct Insertion of Simulated Malfunctions.	1.a. Select malfunction display. b. Select system. c. Insert/Delete/Inhibit malfunctions.	1.a. Index of malfunctions by system. b. Malfunctions available for insertion on a system. c. Action malfunctions.	1. Malfunctions must be able to be inserted directly from the Experimenter Station, in support of experiments in the development of manual instructional techniques, where advanced display and control capabilities are also available.
2. Preprogram Automatic Malfunction Insertion.	2.a. Select preprogramming mode. b. Identify simulator conditions defining time of automatic malfunction insertion/deletion. c. Identify malfunction tion for automatic insertion/deletion. d. File preprogramming statement. e. Exit preprogramming mode.	2.a. Preprogramming Mode. b. Malfunction Selected. c. Conditions selected. d. Simulator Freeze Status.	2. Preprogramming malfunction insertion can facilitate the standardization of training and performance evaluation. Experimentation is required, however, in the development of ways of automatic malfunction insertion which are realistic and compatible with the training task and with the trainee's capabilities at specific stages of learning.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
3. Inhibit Insertion of Preprogrammed Malfunction	3.a. Select display of preprogrammed mission parameters. b. Inhibit malfunction insertion. c. Inhibit discrete malfunctions directly (Ref. Item 1).	3.a Preprogrammed mission parameters for current mission. b. Malfunction selected for deletion. c. Inhibit function.	3. Instructional flexibility and optimum utilization of instructor talents require a capability for instructor override of automated features based on judgments of effective guidance techniques. The FCIS must support experiments in varying the mode of instructor override in achieving specific training goals.
4. Override Automatic Malfunction. Insertion with Manual Insertion.	4.a. Select malfunction display. b. Select system. c. Select malfunction to insert d. Insert selected malfunction.	4.a. Index of malfunctions by system. b. Malfunction available on system. c. Malfunction status.	4. (See 3 above.)

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
5. Prepare Demonstration. (Must be Manual)	5.a. Prepare recording device. b. Identify task to be recorded. c. Set simulator initial conditions. d. Select demo mode. e. Select record sub-mode. f. Remove FCIS from freeze. g. Execute task for recording (aural will be recorded for all DEMO).	5.a. Program Mode Status. b. Initial Conditions Index. c. Conditions selected for start end of demonstration. d. Task Index. e. Task selected for recording. f. Freeze status.	5. The demonstration of procedures, tasks and engagements provides the crew with a standard by which to guide and judge his own performance. Automated demonstrations can standardize demonstrations,and can provide a basis for experimental evaluation of various ways of structuring and employing automated demonstrations. Aural instruction to the crew should be recorded with each demonstration, to aid in standardization.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
6. Playback Demonstration in Manual Mode.	6.a. Select demonstration b. Select fast, real-time or slow playback c. Select demonstration mode. d. Initiate demonstration.	6.a. Demonstration Mode Status b. Demonstration Index. c. Demonstration selected. d. Playback speed selected. e. Demonstration status. f. Freeze status. g. Demonstration Segment Display. h. Reset to selected demonstration segment. i. Terminate demonstration.	6. Instruction consists largely in showing the student what *to do and how to do it, then* observing and critiquing his performance. Manual demonstrations by the instructor are used extemporaneously, where the instructor feels that they are appropriate. Manual selection of standardized demonstrations will support experimentation in the best way of using the demonstration as a teaching tool under a variety of circumstances. The capability for demonstrating discrete task segments will further facilitate the development of effective training utilization of this automated feature.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
7. Preprogramming Automatic Demonstration Playback	7.a. Select preprogramming mode.	7.a Program Mode Status.	7. The experimental development of methods of automating instructor functions requires that demonstrations be preprogrammed within automated instructional sequences.
	b. Select demonstration index.	b. Demonstration Index.	
	c. Specify conditions to start demonstration.	c. Demonstration selected.	
	d. Specify demonstration.	d. Program Index.	
	e. Specify demo playback mode.	e. Mission selected.	
	f. Specify aural off (optional)	f. Mission conditions available for mission selected.	
		g. Demonstration Insert Status.	

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
8. Record Crew Performance (Manual Mode).	8.a. Initiate performance recording. b. Terminate performance recording.	8.a. Record Status.	8. Crew evaluation, guidance and debriefing requires that relevant performance data be available as required by the instructor or experimenter. This capability will facilitate crew debriefing, and later evaluation of sources of error. Any simulator parameter is available for recording. During preprogramming, the experimenter will select parameters appearing to be relevant to specific tasks and task elements.
9. Preprogram crew performance recording.	9.a. Select preprogramming mode.	9.a. Preprogramming Mode status.	9. The automation of instructional functions can reduce requirements for instructor training and participation in training, and it can help to standardize the instructional process. This capability will support experiments in the development of effective methods for recording crew performance at preselected, critical training stages, without direct instructor participation.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

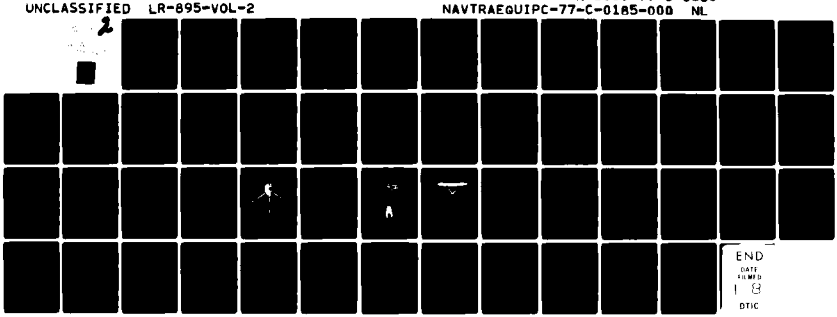
EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
10. Playback crew performance, Manual Mode.	10.a. Select performance playback mode.	10.a. Playback mode status.	10. Immediate confrontation of the crew with a record of their performance can reduce instruction time. This provision will support experimentation in the use of crew performance playback as an instructional tool in manually-controlled instruction.
	b. Identify crew performance for playback.	b. Perform and record available; selected performance and performance segment.	
	c. Initiate playback of crew performance.	c. Playback time selected.	
	d. Freeze playback; continue playback.	d. Playback status.	
	e. Select segment of performance record for playback.	e. Values of parameters recorded.	
	f. Reset to selected segment.	f. Freeze status.	
	g. Initiate playback of selected performance segment.		

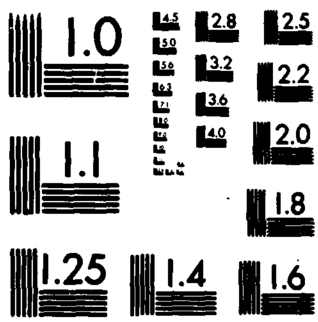
TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
11. Preprogram Variations in Task Difficulty Through Modification of Simulated Tank Dynamics and Motion Equations.	12.a. Select preprogramming mode. b. Select display of equations to be modified. c. Select equation elements for modification; identify *new values.* d. Select display of conditions to be used to initialize simulator to new values. e. Store new values and initializing statements.	12.a. Preprogramming mode status. b. Tank equations, elements and access codes. c. Elements selected for modification. d. Values to be inserted. e. Simulator conditions to be used to initialize new equations f. Conditions and values inserted.	12. Reducing, or increasing, task difficulty can promote more effective learning process. Tank dynamics and simulator motion are sources of difficulty in the development of skill in some motor tasks. Preprogramming variations in these simulation areas will support the development of methods of automatically facilitating learning.

AD-A091 423 SINGER CO BINGHAMTON NY LINK DIV F/G 19/3
DESIGN DEFINITION STUDY REPORT. FULL CREW INTERACTION SIMULATOR--ETC(U)
JUN 78 N61339-77-C-0185
UNCLASSIFIED LR-895-VOL-2 NAVTRAEQUIPC-77-C-0185-000 NL

2





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
12. Manually Modify Simulator Motion Axes to Vary Task Difficulty.	12.a. Select manual mode.	12.a. Simulator Status.	12. Manual locking and release of tank axes must be evaluated as a real time tool for direct instructor participation and guidance.
	b. Select display for axis stabilization.	b. Axis stabilization equations.	
	c. Select equation element for modification.	c. Selected equation element.	
	d. Identify required equation element value.	d. Selected element value.	
	e. *Insert new equation* value.	e. *Modifies value.*	
13. Manually Vary Simulated Environmental Conditions.	13.a. Select manual mode.	13.a. Simulator status.	13. A capability is required for evaluating extemporaneous variations environmental effects as real-time, manual teaching tools. Manual control can permit individualized
	b. Select index of environmental conditions and current values.	b. Environmental conditions and current values.	
	c. Identify condition to be modified.	c. Selected environmental condition.	
	d. Select new value.	d. Selected value.	
	e. Insert new value.	e. Insertion feedback.	

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
14. Preprogram Automatic Sequencing of Training Tasks and Maneuvers.	14.a. Select preprogramming mode.	14.a. Preprogramming Mode Status.	14. Preprogrammed presentation of tasks, maneuvers, and exercises can minimize instructor participation and enhance training standardization. This feature will permit experimentation in methods of task sequencing.
	b. Select display of tasks, maneuvers and demonstrations for automatic sequencing.	b. Tasks, maneuvers, and demonstrations to be sequenced.	
	c. Identify task, maneuver and demonstration sequence.	c. Sequence selected.	
	d. Select display of initial conditions associated with each task, maneuver, or demonstration.	d. Initial conditions available.	
	e. Insert selected sequence of tasks, maneuvers, and demonstrations.	e. Initial conditions selected.	

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
15. Manually Identify Next Task in the Preprogrammed Sequence, for Presentation to Crew.	15.a. Select manual mode. b. Select display of tasks, maneuvers, and demonstrations in current preprogrammed sequence. c. Identify preprogrammed tasks, maneuvers or demonstration for presentation. d. Insert selected program for implementation. e. Release simulator for presentation or practice.	15.a. Simulator status. b. Current sequence of preprogrammed tasks, maneuvers and demonstrations. c. Selected task, maneuver or demonstration. d. Program insertion.	15. Task sequencing must be sufficiently flexible to respond to specific problems experienced by specific crews. The capability for manual designation of the next task in a preprogrammed sequence will permit evaluation of sequence flexibility as a real-time instructional tool. Experiments will also be possible, in using this feature, in crew self-instruction.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
16. Preprogram Automatic Task Sequencing; Vary Task Difficulty Based on Student Score.	20.a. Select Preprogramming mode. b. Select task sequence index. c. Select sequence for prcgramming. d. Identify difficulty level, relative importance of each sequenced task. e. Identify student criteria to be used to govern selection of next task for practice.	20.a. Preprogram Mode Status. b. Task Sequence Index. c. Select task sequence d. Difficulty level, relative importance assigned to each task. e. Index of crew performance criteria. f. Criteria selected for sequencing.	20. Automated instruction must permit variations in the presentation of training problems, to account for unanticipated problems in crew perception of the problem, and in developing appropriate responses to it. Task sequencing based on crew performance will permit the evaluation of various methods of relating problem presentation and student characteristics.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
17. Override Preprogrammed Task Sequence.*	17.a. Terminate current automatic task sequencing.	17.a. Automatic sequence freeze status.	17. The ability for the instructor, or the crew to override a preprogrammed task sequence will support experiments in the flexible employment of the automated features.
	b. Select display of available preprogrammed tasks.	b. Preprogrammed task index.	
	c. Select task for practice.	c. Task selected.	
	d. Release simulator for practice in selected task.		
	e. Terminate practice on selected task.		
* May also be accomplished by crew.	f. Reset to preprogrammed sequence.		

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
18. Preprogram Crew Performance Feedback.	18.a. Select preprogramming mode.	18.a. Preprogram Mode Status.	18. Performance feedback, at the right time and in the right form, can facilitate learning. Improperly used, it can retard learning, or promote learning of appropriate responses. This feature will support experiments in the formatting and automated introduction of performance feedback as a way of facilitating learning and transfer.
	b. Review Index of parameters available for feedback.	b. Parameter Index.	
	c. Select parameters for feedback; select media for feedback.	cc. Selected parameters.	
	d. Define conditions to be used to initiate feedback.	d. Selected media.	
		e. Selected feedback - initiating conditions.	
19. Manually Provide Crew Performance Feedback.	19.a. Identify parameters for feedback.	19.a. Selected parameters.	19. This feature will support experiments in the use of feedback techniques in real-time, manual guidance.
	b. Select feedback media and initiate feedback message.	b. Selected media.	
	c. Terminate feedback.	c. Feedback display status.	

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
20. Preprogram Feedback to Instructor.	20.a. Select preprogramming mode. b. Select index of available feedback parameters. c. Identify parameters for feedback. d. Select feedback media.	20.a. Programming Mode Status. b. Feedback Parameter Index. c. Parameters selected for display. d. Available display media. (1) Graphic display, real-time plot of at least two sets of two simulator variables each. (2) Plot of standard performance. (3) Hard copy printout. (4) Driving, systems and gunnery performance data. (5) Training status and score data. (6) Training exercise summary.	20. Instructor feedback is essential both in real-time manual instruction and in evaluation, and in the diagnosis of learning problems. Experiments are required to establish the form of feedback required to support training in various tasks, and to define optimum places in the training process for the presentation of performance feedback to the instructor.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
20. Continued	20.e. Select standard performance pre-programmed for performance comparison.		

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
21. Select Feedback Display(s) as Required; Provide Hard-Copy of Display.	21.a. Select display media. b. Identify parameters for display. c. Initiate display. d. Select printout.	21.a. Display media selected. b. Available parameters for display. c. Parameters selected. d. Printout.	21. Complete flexibility in real-time instructor guidance and evaluation requires the development of performance display formats, and of methods of employing these displays in monitoring, diagnosing, evaluating and guiding crew performance. Hard-copy printouts are essential for crew debriefing and for the development of improved formats. They can also be used in evaluating the overall quality of the training approach used.
22. Provide Feedback Display to Crew	22.a. Select crew feedback method (visual, optics, and to motion). b. Activate crew.	22.a. Crew feedback status	22. Experimentation is essential in the selection of data for crew feedback, in the development of optimum methods and in defining the appropriate point in training for the introduction of special feedback data.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
23. Preprogramming Simulator Data Recording.	23.a. Select preprogramming mode. b. Select conditions to be used to initiate recording of specific data. c. Select parameters to be recorded under specific sets of conditions. d. Establish data recording, sampling rate. e. Select media for recording of specified data under specified conditions.	23.a. Display mode. b. Selected conditions. c. Parameters selected. d. Sampling rates available. e. Sampling rate selected. f. Media selected for recording.	23. Data recording can provide the basis for evaluations of crews, methods, equipment and training techniques. Extensive experimentation is required, however, in providing essential data in useful formats. Preprogramming the data recording function can permit experiments in designing when and what parameters are to be recorded for various purposes.

TABLE 6-1 EXPERIMENTATION CONTROL AND DISPLAY REQUIREMENTS

EXPERIMENT FUNCTION	ACTION	DISPLAY	RATIONALE
24. Request Data Recording, On-Line.	24.a. Display data available for recording. b. Select data recording sampling rate. c. Select media for data recording. d. Select parameters to be recorded. e. Initiate and terminate recroding.	24.a. Available data. b. Sampling rates available. c. Sampling rate selected. d. Media selected. e. Parameters selected. f. Recording status.	24. Real-time data recording can provide essential information for crew evaluation and for the diagnosis of learning problems. Experimentation is required in selecting, summarizing and formatting data for immediate and direct utilization.

SECTION VII

7. FCIS SIMULATION REQUIREMENTS

Before the M60A3 tank crews can be expected to operate at near combat levels of proficiency, they must have practice in training settings in which both the M60A3 vehicle operational characteristics and the dynamic tactical environment are represented. The training settings must promote realistic interaction among the crew and the information portraying the environment, and also induce the correct articulation of individual and crew actions and responsibilities.

Much of the information available to the crew in combat is aural with a significant amount sensed as motion and vibration. The synthesis and production of aural cues representing the tank environment is quite straightforward, and does not require any technological development. Similarily, adequate motion and vibration cueing can be accomplished by state-of-the-art systems developed for other surface vehicle training systems. Visual systems, available in the current technology, on the other hand, cannot come as close to reproducing the environment sensed by the tank crew as aural and motion cueing systems. This is due to the extreme difference in information content, of visual scenes as opposed to the information content of tank motions, and the sounds made by the tank, its systems, the weapons, and other effects associated with the armor battlefield.

Tables 5-2 through 5-5 summarize the training objectives for the M60A3 tank crew which the FCIS device should be capable of supporting. These objectives are treated on an individual basis basis, for the tank commander, gunner, loader and driver, but each involves intimate and detailed performance on the part of each other member of the crew. The information requirements associated with each training objective are also included in the Tables. In addition, the criticality of each objective for total crew combat skill has been assessed. Each objective is important, but some are more crucial than others to combat effectiveness, and to crew interaction training.

Information requirements are listed in visual, motion, and aural cue categories, to indicate the complexity required of the simulator in support of crew interactive training.

7.1 Visual Simulation Requirements.

Fortunately, effective interactive crew training does not require the crew to respond to all of the information available in a typical tank combat situation. At the same time, interactive crew training does impose specific demands on the visual simulation technology (and cost) which must be weighed against their effect on crew training.

7.1.1 Visual Cue Functions. Visual cues in the tank combat situation can stimulate at least three levels of crew function.

At the most complex level, visual cues are used to discriminate the presence or activities of concealed vehicles, personnel, or other equipment. This level of discrimination differentiates small differences in color, shading, contrast, and shape in distinguishing among non-threatening terrain, vegetative and cultural features and hostile elements and events. Skill in discriminating visual information, at this level, is essential to effective tank employment, particularly on the part of the tank commander. This level of visual skill has little to do with the ability of a crew to develop effective interactive skills. Also, it can be trained in relatively inexpensive individual training situations, using both synthetic and natural cueing.

The second level of visual cue function concerns the initiation of individual and crew procedures. Almost all individual and crew tasks in the M60A3 are performed as standard, prescribed procedures, defined by the tactical situation existing (and perceived) at a given time. Visual cues, and sometimes, motion,vibration, or aural cues can tell the crew which procedure to execute, but more often, visual cues serve as the initiating stimulus. Visual cues need only support discriminations such as threat vs. no threat, tank vs. truck, truck vs. personnel, personnel carrier vs. foliage, foliage vs. helicopter, helicopter vs. aircraft, and so on. Visual cues do not involve the discrimination of subtle differences across the visual scene, but act only as determiners of which visually-cued actions are to be taken, and when they are to begin. This level of visual cue supports crew interaction training by telling the crew that a specific crucial event has taken place. It also helps the crew to identify which procedure is appropriate to the event, and it provides feedback to the crew about the accuracy and effectiveness of its responses. In context with motion and aural cueing, and with the tactical information provided in maps, charts, briefings, and communications, it provides for an almost infinite variety of situations for crew discrimination and practice.

The third level of visual cue function is in helping to define the complexity of the situation in which the crew must interact. The tank crew operates in a hemisphere which includes a 360° horizontal field of view and, for the tank commander, something like a 240° field of view in the vertical dimension. Events having significance for the crew can occur in many places in this hemisphere, in sequence or all at once. Part of the crew's responsibility is maintaining surveillance throughout this hemisphere, and to detect and respond to important events with as little delay as possible. The tank

commander and the loader, when the loader can operate with his head out of the hatch, are the only members of the crew in contact with this total hemisphere. The gunner's view is limited by the restricted fields of view of his optics, while the driver's view is constrained either by his periscope, or by the turret, fenders, and the front slope of the hull.

7.1.2 Field of View. Two major considerations limit the need for a realistic field of view for the tank commander and the loader. First, most events of significanct, except the approach of airborne threats, take place on the surface of the terrain. A total vertical field of view (90° to the horizontal) is needed for terrain surveillance in only very exceptional circumstances (at the bottom of a canyon, etc). It is even less of a requirement for the detection of airborne threats. Fixed-wing aircraft, operating in the air-to-ground mode, must make runs at no more than about 30° to the horizontal, to permit weapon accuracy and to avoid flying into the ground. Helicopters are restricted to even lower aspect angles, because of their need to use terrain features, buildings and vegetation for cover during air-to-ground operations.

The second consideration deals with the surveillance functions of the loader and the tank commander. The loader does not search in a 90° sector, or a 180° sector, or in a 45° sector: he looks in the sector defined for him by the commander, to meet the requirements of the tactical situation. The field of view available to him in training has little to do with the area he will search in combat; he will search the area in which it is necessary to search. The tank commander will also search where the situation demands. His responsibility is somewhat different from that of the rest of the crew; he is, in the Armor unit, not only a trainee, but also the crew's instructor. He searches, detects, acquires, allocates, designates, and directs in response to tactical situations defined by by the FCIS, both for practice in tactical decision-making and to exercise and train the entire crew. In combat, as in training, he will search the area available; in the FCIS, the most important aspect of the commander's field of view is not so much its absolute size as its ability to demand complex judgments on his part, and complex responses on the part of the entire crew.

Each member of the crew requires something different of the visual simulation system, although each must see enough of the tactical situation to establish a context within which to fit his own tasks and functions. Each crew member (except the commander) has restricted contact with the visual scene around the tank because of the limitations imposed by his position and by his vision devices. During periods of contact with the enemy, and during buttoned-up operations, even the tank commander's view is severely limited, making popped-hatch and closed hatch operations extremely important for training, especially for the commander.

7.1.3 Tank Commander Visual Requirements. The tank commander must have visual contact with the tank environment from the closed hatch (vision blocks and optics) position, with the hatch cracked to provide overhead protection from artillery, and from the open hatch (unaided and vinocular vision) position, to permit him to operate as he would in the tank itself. The closed and popped-hatch positions are important in training the tank commander to compensate for field of view limitations and in training him to place greater surveillance responsibilities on the rest of the crew, during periods when his vision is restricted. Open hatch operations are equally important, in training the commander to make effective use of the loader's capabilities for surveillance and target detection, and in training him to search the entire area with both his unaided vision and with his binoculars. Open hatch simulation is also important in training the commander to perform the procedures resulting from a target detection, quickly and accurately. In the open-hatch situation, when the commander detects a main gun or coax target, he must simultaneously lay the main gun and the coax to place the target in the gunner's sight, and drop into the cupola to range on the target. At the same time, he must search the entire area for other targets and potential threats, allocating engagement functions between the gunner and himself, depending on his perception of the total situation at the time. Closed-hatch operations are somewhat simpler, although they do not require the tank commander to move into and out of the hatch, they do require more careful surveillance by the entire crew, more detailed coordination with adjacent elements and support ing units, and more deliberation when moving about the battlefield.

The tank commander's visual cue requirements stem from his dual responsibilities as crew tactician and crew coordinator. The commander has more information available to him than any other member of the crew. He uses this information in making decisions as to the best ways to employ the tank and the crew, and in detecting, engaging, and destroying threats to the tank and its mission. The tank commander needs to be presented with the kind of visual information used in perceiving and assessing tactical situations, and in executing the procedures involved in implementing those decisions. In the FCIS, the tank commander has five basic visual cue requirements.

7.1.3.1 Terrain Visual Cues. The tank commander obtains a great deal of tactical information from his examination of the terrain in the battle area. He sees where threats might be deployed by examining available cover and concealment, and he sees where his own tank might move and position itself, by noting similar areas of cover and concealment, advantageous firing positions, and potential fields of fire to be avoided. Because he is able to identify places in which threats might be hidden, or in which they might appear, he not only plans the tank's route for maximum security and effectiveness, but

he also detects and engages targets quickly; frequently before they can become serious threats.

The driver's field of view is adequate for negotiating terrain in the immediate vicinity of the tank, but the tank commander's guidance is essential in many situations, since he can see more of the terrain surface and the tactical situation than are available to the driver. The commander searches for good routes for the tank, for surface characteristics that are compatible with the tank's capabilities and the requirements of the situation at the time. He directs the driver in the selection of a route and in moving over that route as efficiently as possible.

The tank commander's use of terrain visual information requires that he have cues to the nature and sizes of major terrain features including hills, slopes, fields, woodlines and woods, ditches, ravines, streams, and bodies of water. The commander also needs cues indicating obstacles to the movement of the tank, and to the nature of terrain surfaces between the tank and its objective. In the FCIS, it is not important that the commander respond to the same cue patterns he would in the real world. Although total realism would be motivating, it would have little effect on the value of the system in crew interaction training, since the commander's function is to direct and coordinate crew responses to tactical events, rather than to sense and perceive the subtle and complex cues that define those events. It is important, however, that the simulated tank and tank systems respond to the differences in features, obstacles, and surfaces portrayed in the visual system, so that the crew will be forced to perform within situations imposed by the commander's terrain-imposed decisions.

7.1.3.2 Control Tank in Formation. The tank commander and the driver maintain the tank in prescribed positions with respect to other tanks in combat or when traveling from one place to another. Spacing and relative positions of tanks in formation is important in combat to assure effective mutual surveillance and fire support, and in road formations to maintain maximum speed and a secure interval. The tank commander's field of view, and his position above the driver permit him to assist the driver in maintaining proper position, especially in combat formations. In tactical operations, the adjacent tank can disappear from the driver's view, behind trees, bushes, knolls, and the driver's own tank, though still visible to the tank commander. The commander is required to see the adjacent, or lead tank, on the terrain surface among those features limiting the driver's visual contact. Some terrain surface detail is also required, to help the commander judge the relative speed and heading of the other tank, and of his own tank. Features of the other tank should become legible with reduced range, to give the commander at least gross cues to its relative distance. In combat formations, the weapon effects of the other tank including smoke, muzzle flash, tracer, and weapon

impact should also be visible to the commander, to permit him to provide realistic support by fire and maneuver.

Night simulation of the other tank must include its thermal image, and images of its tactical driving lights, in the front and rear.

7.1.3.3 Weapon System Visual Cues. The commander uses all of the tank's weapon systems to engage, destroy or suppress all of the kinds of threats the tank could encounter, including both surface and airborne targets. Most commanders using the FCIS will have become proficient in firing the main and coax guns, and in firing the .50 caliber machine gun, but few will have had any practice in coordinating commander and gunner use of these weapon systems in anything like tactical situations, while directing the movement and employment of the tank. The commander must be able to detect multiple targets of different types and at different ranges, so that he can practice making and implementing decisions concerning the assignment of target priorities, the allocation of weapons to targets, the simultaneous engagement of two or more targets with two or more weapons, and the direction of tank movement as appropriate to the evolving situation. Targets must include stationary and moving tanks, trucks, armored personnel carriers, troops, high-performance aircraft, and helicopters. Concealed targets must also be available; with associated indications of target activity including movement, glint, flash, smoke, and dust. In the case of concealed tanks and other hard targets, the effects of ricochets of machine gune fire must be available. Cues to multiple targets are important, to force the commander to make decisions about which target(s) to engage first, whether to engage more thanone at a time, whether to evade some while engaging others, and how to most effectively allocate the tank's weapons and the crew's capabilities in effective engagements and/or evasive maneuvers.

7.1.3.4 Machine Gun System Employment. The commander uses the coax and the .50 caliber machine guns not only to engage and destroy specific targets, but for ranging, suppressive fire, for information-gathering and, on occasion, to start fires to burn out cover or to force threats into the open. This function requires that realistic machine gun tracers, ricochets, and effects be simulated. Tracer burnout must occur at the proper range and the target area must absorb fire, or produce ricochets, depending on whether hard targets are present or not. Secondary explosions should also result from machine gun fire into concealed target areas, as appropriate. Fires in vegetation are desirable, but of minor value in the context of full crew interaction. The effects of suppressive fire is to produce erratic fire (tracers) from automatic weapons fired by troops and from lightly-armored vehicles, and to cause these sources of fire to stop firing or to produce erratic flights of ATGM's where suppressive fire has been directed at the guidance personnel.

7.1.3.5 **Threat Weapon Impacts and Near Misses.** The commander attempts to direct the tank and the crew to avoid being engaged by threat weapons, but the complexity of the battlefield and the capabilities of the threat forces make hits on the tank, and near-misses inevitable. Hits can be highly motivating to the crew, but beyond this, can provide important information to the crew and the tank commander concerning the validity of their decisions and actions up to that point. When hits and near-misses can be associated with weapon firing effects, they can provide valuable information for the detection and engagement of threats.

Visual cues associated with hits on the tank are not especially prominent or meaningful in the context of the noise, shock and vibration that accompany them. Visual cues to near misses and to correlated weapon-firing effects are more meaningful as an aid in locating, evading, and engaging the weapon doing the firing. Tracers are the most prominent visual cue to near-misses by gun-launched projectiles, but they can only be seen from abreast of or from behind the projectile. Bodies of guided missiles can be seen, providing both velocity and aspect angle information. Visual cues to missile body movement and orientation are essential in practicing evasive maneuvers, although in most cases, the tank commander will not have enough time to interpret these cues and to direct evasive action.

7.1.4 Gunner Visual Cue Requirements. The gunner sees the battlefield through narrow unity-power and magnified optics, with direction defined by the position of the turret and the main gun; he sees only where he, or the tank commander has pointed the optics. The gunner's primary visual responsibility is in identifying the target designated by the commander so that he can lay on it, engage it, and destroy it as rapidly as possible.

When the tank is not in direct contact with the enemy, the gunner searches an assigned area, looking for threats and signs of threat activity, to supplement the surveillance performed by the commander and the loader. During these periods, he slews the turret to permit wide area coverage, using his optics to search at long range. In some situations, he may also assist the driver in evaluating potential routes beyond the driver's field of view or range of vision, while the tank commander and the loader maintain the search for threats. The gunner can sometimes recognize surface characteristics, obstacles, terrain features, buildings, and vegetation having significance for the driver in controlling tank movement, cover and concealment. The gunner's tasks require him to observe the following types of visual information.

7.1.4.1 Terrain. The gunner must see major terrain features, surfaces, vegetation, buildings and obstacles which tell him where threats could be and where they are not likely to be. He must also see the features used by the tank commander as landmarks in helping him to find designated targets. ("Behind the small bush; beside the large ditch," etc.)

The gunner's view of potential obstacles and terrain surfaces must also give him enough information to permit him to help the driver in selecting routes which the driver cannot evaluate for himself, from his point of view in the hull. The gunner, with his narrow fields of view, will have difficulty in estimating range. Textural cues which vary with distance, are needed in the terrain, to give the gunner a feel for speed and relative distance. Differential color and clarity, with range are also needed to provide the gunner with an impression of distance and depth in the scene available to him through his optics. Thermal-sensor images are extremely important in helping him learn to use the thermal sights in finding concealed targets in the day, and in laying on concealed and unconcealed targets at night.

7.1.4.2 Targets. The gunner must see the targets designated by the commander, and he should also see targets which the commander may have overlooked, so that he can alert the crew. Like the commander, the gunner needs training in discriminating targets in complex backgrounds, and under all conditions of concealment, range and visibility. This training can be provided in more economical settings than the FCIS, without compromising individual training with crew training requirements. Targets presented to the gunner must be differentiated as to type, range, and movement, to provide the gunner practice in making the proper response to different target conditions.

The gunner must also be able to see more than one target, or target indication at a time. This will provide valid practice in identifying the target designated by the commander, and in judging which target to engage, with what procedure, and in what order, when the tank commander must leave the decision to the gunner.

Since most targets engaged by the tank are at least partially concealed, the gunner must have some definitive cues to target type and location, in the form of weapon flash, smoke, tracers, dust, glint and movement. During periods of surveillance, these indications are needed to attract the gunner's attention when the tank commander is occupied in some other sector.

7.1.4.3 Weapon Effects. The gunner observes the effects of the weapons he and the tank commander fire in order to decide on a subsequent course of action. If the target is hit and appears to be destroyed, other targets can be engaged, or the

crew can resume its search for other targets. If the target was missed, the information provided by the flight of the tracer element and by the impact of the round on the ground short of, or to the side of the target, is applied in correcting the aim for the next round.

The effects of the gunner's own weapons are important in reporting, warning, anticipating, and dealing with the flash and obscuration accompanying firing. Muzzle flash is a problem at night, because it destroys the gunner's night vision. As he fires at night, the gunner must close his eyes momentarily so that he can preserve his night vision for sensing the round as it impacts in the target area. The gunner must see the tracers of the main gun round, the coax, and of the commander's .50 caliber machine gun, to permit him to adjust his own fire and that of the commander.

7.1.5 Loader Visual Requirements. The loader's visual responsibility involves surveillance of the battle area from the loader's hatch, either with the hatch open, or with the loader's rotatable unity-power periscope. When the tank is in contact with the enemy, the entire crew searches the area for threats and other significant visual information, in areas assigned to the platoon and to the individual crew. Usually, the loader searches to the rear, and to the flank if the flank is not covered by an adjacent tank. The loader has a restricted area of responsibility, even though he has a very large field of view when he operates with his head out of the hatch. When the crew travels with hatches closed, the loader's field of view is drastically restricted by the periscope, which he must turn, elevate, and depress manually.

7.1.5.1 Terrain. The loader must be able to see a terrain image similar to that seen by the tank commander in the head-up or vision block mode, which he can search with unaided vision. The gunner must see major terrain features, surfaces, and obstacles, so that he can anticipate tank locations. The loader will provide little if any assistance to driver if the tank commander is too busy to help him since the loader will also be busy with the main gun or with the coaxial gun. When the commander is occupied with communications or other activity not associated with an engagement, the loader can provide steering directions to the driver when negotiating confined areas or obstacles in the immediate vicinity. Thus, he should see slopes, surfaces, ditches, vegetation, roads and buildings in the terrain foreground.

7.1.5.2 Targets. The loader must also see targets appearing within his range and vision, up to 1,000-1,200 meters, so that he can alert the crew to their presence. He must also see secondary indications of more distant activity, including smoke, flash, glint, and dust. Movement cues should also be provided, in the 600 to 800 meter range. Since the loader does not have

an optical magnification or thermal system available to him, he will report signs of possible threat activity to the tank commander who will examine the areas in more detail with binoculars, periscope or thermal sight.

7.1.5.3 Weapon Effects. The loader senses rounds fired by the gunner to help in adjusting fire into the target areas. Because he will usually be inside the turret, loading the main gun or maintaining the coax, he will perform this function only on rare occasions. The loader may observe the effects of weapons fired at the tank, in the form of tracers, missiles, and impacts on the terrain, but when fire is observed in the vicinity of the tank, the loader will move into the turret, either for protection, or to service the tank weapons. He should see the same effects of threat fire seen by the commander, during the limited time he will have visual contact with the terrain.

7.1.5.4 Own Tank. When the loader provides steering guidance to the driver, he needs to see everything that indicates the position of the front and rear of the tank hull. He does not need a high-detail image of the hull, but only enough information to tell him where his tank is positioned with respect to the turret, and with respect to obstacles in the immediate vicinity.

7.1.6 Driver Visual Requirements. The driver exercises control over tank movement, selecting and negotiating routes that provide the speed, maneuverability, and agility required at the time. He also provides cover, concealment and advantageous observation and firing positions, to the maximum extent possible. Much of the driver's performance is directed by the tank commander, but total crew efficiency and effectiveness depend heavily on the ability of the driver to perceive and respond to the total tactical situation, exercising control with a minimum of specific direction. For this reason, the driver must have detailed information about the terrain and features in the immediate area, and at least general terrain information at weapon ranges. For the driver, the immediate area of concern is the area about 200 meters in front of the tank. Depending on the terrain and the position of the tank on the terrain, the driver may observe significant information for over 3,000 meters. Most of the information relevant to the drivers tactical task is, in the North American or central European environments, within 1,000 meters.

7.1.6.1 Tactical Terrain. The driver needs two types of terrain information. The first type permits him to perform terrain evaluations similar to those performed by the tank commander, the loader, and the gunner as they search the terrain around the tank. The driver tries to identify terrain, vegetation and cultural features which might conceal and support the movement of threats. He needs to perform his analysis

in picking an expeditious and secure route to the objective, by anticipating areas which might be threatened by enemy elements. As he searches in the distance, he looks for terrain features that could conceal a threat, for fields of fire which he should avoid, and for features which he might use in concealing his own tank from the enemy. In planning his route, he also looks for specific features such as roads, bridges, marked mine fields, streams, and other obstacles to movement.

7.1.6.2 Immediate Terrain. Because he must negotiate terrain in such a way as to maximize effectiveness and immediate security, the driver's interest in the immediate vicinity is of greater concern than that beyond one or two thousand meters.

The driver must respond to variations in terrain features within the tactical context, consistent with the needs of the gunner and the commander at that time. In effect, the driver must make and implement decisions about the terrain in the immediate vicinity, which have differential impact on the mission and on the crew as a whole. The driver must be able to select surfaces to optimize speed under some circumstances, cover under others, and on other occasions, smoothness. Road surfaces such as hard dirt, soft dirt or sand, and rough surfaces such as rocks or other uneven surfaces must be differentiated. The driver must also see terrain and cultural features which could provide obstacles to the movement of the tank. These would include buildings, trees, slopes, and ditches, as a minimum. It might also include walls, streams, and swamps. Although some of the obstacles are negotiable, some would stop the tank. These same elements make it possible for the driver to exercise judgment in route selection to improve conditions of motion, vibration, and exposure on the rest of the crew, and to enable them to practice anticipating and dealing with perturbations in tank movement.

7.1.6.3 Weapon Effects. Each member of the crew must attempt, when possible, to sense the impact of rounds fired by the gunner and the commander. Since the eyepoints of the crewmembers doing the firing are close to the weapon axes, they are the most severely affected by the target obscuration produced by the smoke, flash, and dust produced by the weapons. The driver is beneath the major obscuration, however, and depending on the terrain and the position of the tank, he may be in the best position to sense and adjust fire. As a result, he must be able to see tracers, smoke, flash and dust resulting from the impact of main gun rounds and rounds fired by the coax and the .50 caliber machine gun. Impacts vary with the characteristics of the point of impact and of the round itself. Hard targets must cause ricochets of machine gun rounds, and bright orange glow resulting from HEAT and APDS rounds. Soft targets, including the ground, must show the dust and smoke resulting from main gun impact.

7.1.6.4 Own Tank. The driver must maintain his orientation, with the hull of the tank and with the turret, in order to anticipate where he is to drive the tank, and where he can expect targets and engagements to take place. Accurate orientation requires that he use the fenders of the hull, and the main gun as it moves across the field of view.

7.2 Motion Simulation Requirements

Motion of the tank over the terrain, along with turret motion, provides useful information to the crew that aids them in the execution of specific functions. Total tank motion vibrations associated with the terrain, track, and engine and transmission, provide the gunner and commander with indications of the route the driver has chosen, his speed, and the ability of the tank to turn and accelerate at any time. Tank motion also distracts the commander and loader, making many of their tasks more difficult (and in some instances, extremely difficult) than the same tasks performed in a stationary mode.

Turret motion also provides information of value primarily to the commander and gunner. When the commander slews the turret, the gunner can anticipate the appearance of a target, and to some extent, where to look for it. By the same token, the commander can monitor the gunner's use of the turret in searching for and detecting targets.

Since the crew does not sense motion as a continuum (except by means of visual cues), full motion is not required at any crew station. Certain physical motions can be limited to motion onset cues washed out at subliminal levels. Because of the cues they provide the driver, gunner, and commander, and the disturbance they represent to the loader, pitch and roll motion must be continued for as long as they occur in the actual tank. Yawing motion due to turn maneuvers and sensed within hull and turret can be eliminated because it does not influence the crew's perception of the gravity vector.

Vibration and shock resultant from main gun firing and movement over the terrain are important to the entire crew during fire control, surveillance, and driving. Movement of optical sighting devices can result in injury to the user if his helmet is not pressed firmly into the brimpad. Training with appropriate vibration and shock cues can establish habit patterns that will help protect the crew.

The most important degrees of freedom of motion for crew training are pitch and roll. Both are more significant to the driver than to other crewmen.

Pitch Motion - Provides indications about tank performance when climbing slopes. When combined with track, engine, and suspension system sounds, pitch motion also indicates whether the slope can be climbed.

Roll Motion - Provides continuous cues as to sideslope orientation.

Motion is important to the gunner as an information source and as a distraction. It is also instrumental in preventing vertigo.

In the stabilized mode, the gunner's sight picture is not influenced by tank motions except during extreme maneuvers. Gunner station motion, when part of the total training environment, can help the gunner reconcile visual scene stability with tank motion when he enters the crew training compartment. This same gunner station motion is also an aid in preventing motion sickness as well as vertigo.

The determination of motion system requirements was made from an analysis of M60 performance data in light of the manner in which the human physiology perceives motion. These analyses yield, not only the requirements, but a philosophy for stimulating these physiological receptors consistent with real-world stimuli.

7.2.1 Tank Motion Data Analysis. In order to define the motion environment of crew members, data from several sources was analyzed. These data were derived from accelerometer measurements taken by Link engineers on an M60A1 tank at Fort Knox, Kentucky, tank manufacturer's test results, various published reports and papers, and an analysis of various physical phenomena. When data from different sources seemed to be in conflict, either a consensus was sought or the one with the greatest apparent physical basis was selected. In addition, during the tank indoctrination course at Ft. Knox, the subjective evaluations of Link personnel were included in the analysis.

Accelerometer measurements employed the following methodology: Four categories of tank motion were measured including turret rotation, main gun elevation, main gun firing, and general hull accelerations resulting from tank movement over terrain.

For turret rotation, a ± 0.25 g accelerometer was mounted on the turret in the vicinity of the air intake and oriented to sense in the horizontal plane. Various combinations of turret rotation, starting and stopping, and various rotation rates were recorded. The objective was to determine maximum accelerations and also to obtain a feel for nominal levels.

After several turret rotation cycles, the accelerometer was rotated 90° to sense vertical accelerations. The sources of vertical accelerations measured were engine vibrations and main gun elevation. The precise location of the accelerometer was known, thereby allowing the calculation of acceleration at any point on the turret. This result implies considering the turret as an inflexible rigid body.

The second data recording session provided the opportunity to record accelerations imposed on the tank as a result of firing the main gun. To accomplish this, two ± 5.0 g accelerometers were mounted to the vertical support structure of the shell deflector frame. It was judged that this rigid structure would

not introduce any unique dynamic responses to the accelerometer measurements. The two accelerometers were mounted to sense accelerations parallel to, and perpendicular to the axis of the gun. Eight rounds of 105mm practice ammunition were fired with resulting accelerations recorded.

In the third session, two accelerometers were mounted on the base of the tank commander's seat. The sensitive axes of these accelerometers were oriented so that accelerations in the vertical and lateral directions were measured while the tank was driven over a muddy course. All data recorded were from a soft, undulating terrain. A variety of maneuvers were executed while driving about the course. Various grade slopes; uphill, downhill, and side-hill were negotiated. Water obstacles and neutral-steer maneuvers were also executed. Results of normal turns, straight running, stops and starts, and other basic driving techniques were recorded.

After all maneuvers were executed and the resultant accelerations recorded, the accelerometers were secured to a structural member at the rear of the driver's seat. Previously executed maneuvers were repeated and the attendant accelerations recorded.

Since the course was muddy, no accelerations were recorded for hard surfaces or paved roads. Also, there were no solid obstacles to traverse; therefore no data was obtained for these maneuvers.

These data were recorded on an FM tape recorder with selected portions transcribed onto a strip chart recorder upon return to Link facilities. Data were analyzed along with data from other sources (see references). Data for hull and turret, presented in Table 7-1, are considered to provide a benchmark for cue analysis and motion requirements.

A brief discussion of these data is required. Longitudinal acceleration of the hull and turret is due to accelerating from a stop based on maximum tank performance on a paved road as determined by Chrysler data. Deceleration is that which results from brake application (not from impact with an object which obviously could produce greater decelerations). Main gun recoil data is based on either over the front or nearly over the front firing. Accelerations on the hull can be derived for other gun azimuths as a function of the ratio of the moments of inertia and the azimuth angle.

Terrain effects data are generally worst-case for going over bumps.

Normal undulating terrain exhibits significantly lower accelerations ($\approx$ 0.02g vertically). Slope operations angles are based on the maximum capabilities of the vehicle. No lateral accelerations were measured or observed due to sliding on sideslope operations.

TABLE 7-1 M60AI ACCELERATION DATA

HULL	
MANEUVER	PARAMETERS
LONGITUDINAL ACCELERATION	0.1g, -0.6g
MAIN GUN RECOIL (long)	-0.2g
(pitch)	±1.0 rad/sec^2
(heave)	±0.2g
TERRAIN EFFECTS (heave)	±1.0g* f=1.0HZ
(pitch)	±0.02 rad/sec^2
	DISPLACEMENT ±0.15 rad
	SLOPE ±0.64 rad
(roll)	SLOPE ±0.30 rad
(lateral)	NONE MEASURED
ENGINE VIBRATION (long)	NO DATA
(heave)	.025g @ 30 HZ
(lateral)	NONE MEASURED
TURNING (yaw)	NO DATA
(lateral)	NONE MEASURED
MACHINE GUN VIBRATION	NO DATA
TURRET ROTATION (lateral)	±0.5g

*This number does not include the effects of bump stop or idler impact. Peaks of 3 to 6g are possible in these cases.

**The quantities in parentheses are average values.

TABLE 7-1 M60AI ACCELERATION DATA (cont'd)

TURRET	
MANEUVER	PARAMETERS
TURRET ROTATION (yaw)	±2.15 rad/sec^2
	±0.392 rad/sec
MAIN GUN RECOIL (long)	-0.4g
(pitch)	±1.0 rad/sec^2
MAIN GUN ELEVATION (vertical)	0.025g
(SAFETY STOP IMPACT)	0.2g
LONGITUDINAL ACCELERATION	0.1g, - 0.6g
TERRAIN EFFECTS (heave)	±1.0g* f=1.0HZ
(pitch)	±0.02 rad/sec
	±0.15 rad (displacement)
(roll)	NO DATA
SLOPE EFFECTS (pitch)	±0.64 rad
(roll)	±0.030 rad
ENGINE VIBRATION (long)	±0.035g @ 5HZ (<.01g)**
	±0.018g @ 15HZ (<.01g)
(heave)	±0.11g @ 5HZ (0.04g)
	±0.03g @ 15HZ (< .01g)
(lateral)	±0.077g @ 5HZ (0.022g)
	±0.028 @ 15HZ (<01g)
TURNING (yaw)	NO DATA
(lateral)	NONE MEASURED
MACHINE GUN VIBRATION	NO DATA
COAXIAL GUN FIRING	NO DATA

Engine vibration data were not recorded longitudinally at the hull; but since the levels (vibration) at the turret in this degree of freedom are low, it can be assumed that they would be low at the hull. The 30 Hz vertical vibration at the hull is assumed to be a harmonic of what is observed at the hull. Higher frequencies resulting from engine vibrations have been recorded. These are harmonics of the lower frequencies and the power spectral density analyses result in such low power spectra that it was felt these should be disregarded at the outset.

No data are available for yaw motion on turning. Also, no lateral acceleration was measured due to turning. Observations of Link personnel who drove the tanks were that neither was felt at the driver's station. Occupants of the turret reported some yaw sensations when turning.

It is difficult, however, to determine if this sensation was induced by some other stimuli. Turret rotation effects can produce start/stop transient accelerations of up to 0.5g at the driver's station.

Effects of these data on the motion training problem are discussed in Section 7.2.3 following a discussion of the manner in which a human perceives motion in Section 7.2.2.

7.2.2 <u>Physiological Perception of Motion</u>. In order to fully analyze the motion simulation requirements for any vehicle, it is important to understand how a human perceives motion, i.e., which physiological receptors are affected, how they function, and how they may be stimulated by a simulator motion system.

Motion is perceived by the human body primarily through three physiological receptor systems: the vestibular (non-auditory labrynth) system, the haptic system, and the visual system (figure 7-1). The auditory system also has some effect on the perception of motion but it is probably a second-level effect. That is the association of certain sounds with past experiences of motion.

In a modern flight simulator, these sensory systems are stimulated by various means. The vestibular system is stimulated by motion systems, vibration systems, and to some extent, G-seat systems (devices for producing sustained acceleration cues). The haptic system is stimualted by G-seat systems, motion systems, anti-G-suit systems, and control feel systems. Visual sensory apparatus is stimulated by both out-the-window visual systems and cockpit instruments. For simulators of other types of vehicles analogs of the above vehicle systems require similar stimuli. These stimuli can be provided by the same types of simulation hardware, excepting of course, anti-G suits and G-seats for armored vehicle simulation.

7.2.2.1 The Vestibular System. The human labyrinth (inner ear) comprises the non-auditory labyrinth or vestibular system and the cochlea. There is one labyrinth located in the temporal bone within each ear. The cochlea, is a part of the auditory system and will not be discussed further, herein. A non-auditory labyrinth is located in the vestibule of each inner ear and hence the name vestibular system. Within the vestibule there are two sets of motion sensors, one linear (the otoliths), and one angular (the semi-circular canals). See Figure 7-2.

The semicircular canals occur as approximately orthogonal triads such that each canal senses rotation about each of the three axes of the head. These axes are essentially parallel to the vehicle body axis system when a crewman is seated erect and facing forward. The sensing mechanism within the semicircular canals is the cupula (Figure 7-3), a valve-like protrusion in the ampulla of each canal. The fluid of the semicircular canal, endolymph, flows through the canal in response to movement of the head, and deflects the cupula. The deflection of the cupula is proportional to the velocity of the fluid flowing past it. Therefore, the semicircular canals sense rotational velocity.

Otolithic membranes exist in both the utricle and the saccule (figure 7-1). The utricle has one otolith and the saccule has two. These maculae are somewhat orthogonal which gave rise to the hypothesis that they work together to provide linear motion cues in the same manner as the semicircular

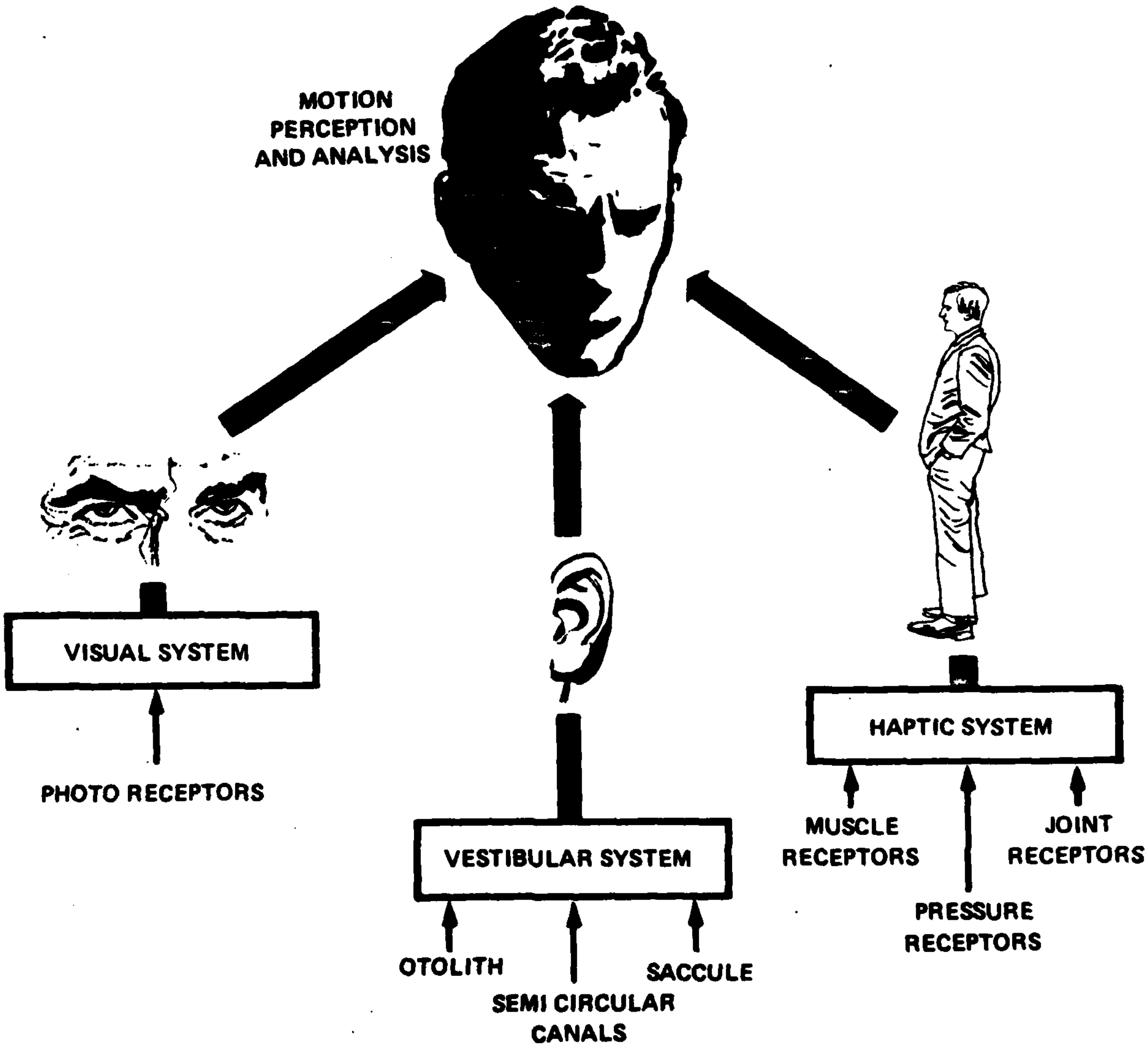


Figure 7-1 Physiological Systems for Motion Determination

canals. Another hypothesis is that the saccule has a dual function, the otolith bearing part responding to linear accelerations in the same manner as the utricular otolith, while that part which is not invested with stratoconia is thought to be stimulated by vibrations in a frequeny of less than 10 Hz to 120 Hz. However at this point the function of the saccule is generally unknown and is assumed to not contribute to the perception of linear motion. In fact the organ is considered vestigial by some. Therefore linear motion is thought to be sensed solely by the otolith of the utricle which is stimulated by linear acceleration. The acceleration deforms the stratoconia (figure 7-4).

As previously stated, each normal human has two complete functioning vestibular apparatus; one on the left side and one on the right side. The acceleration and velocity information from the two apparatus are summed synergisticly. Mathematical models have been developed which represent the functioning of the vestibular system.

7.2.2.2 The Haptic System. The haptic system provides the individual with a sensitivity to the world adjacent to his body. It is the "body feel" sensory system. Another way of defining the haptic system is by its constituent elements; the muscle receptors, the joint receptors, and the pressure receptors. These receptors all contribute to the perception of motion. The muscle receptors respond to either extension or contraction of the muscles as they react to motion of the body. These sensations appear to be a measure of muscular effort and not muscular length. For example, when the pilot is subjected to accelerations which impart a force to his head, the neck muscles exert in an attempt to restrain the head. It is the effort that is sensed by the muscle receptors and is used to interpret motion. The joint receptors differ in that they are stimulated by position. These receptors provide information relative to skeletal attitude. It then follows that since certain skeletal attitudes can be associated with certain body movements these receptors may provide information concerning this movement.

The third category of haptic sensory apparatus is the pressure receptors. These pressure receptors seem to fall into two categories; deep pressure receptors and cutaneous receptors. These receptors, when they are deformed, provide a cue relating the cell deformation to a force or a force change to a specific body movement.

In addition, body hair plays a roll in the sensation of motion through hair cell detectors. For example, if the body is lightly rubbed in a manner such that the skin is not deformed, information relating relative motion between the body and whatever is rubbing against it is transmitted by these hair cell detectors. When the human body is moving,

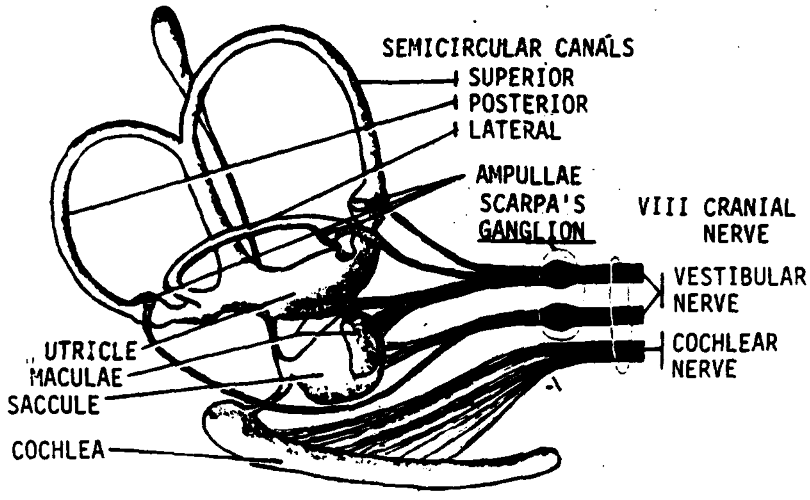


Figure 7-2 Angular Motion Sensor Semicircular Canals

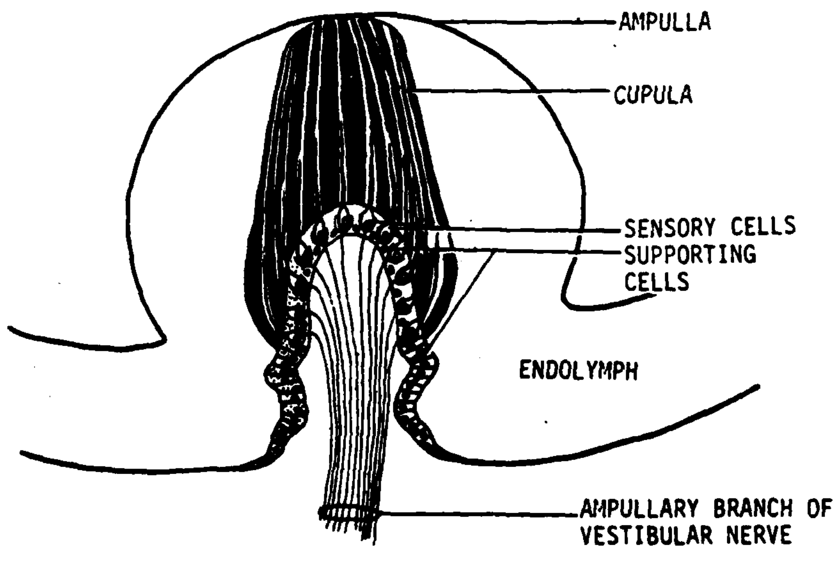


Figure 7-3 Semicircular Canal Cupula

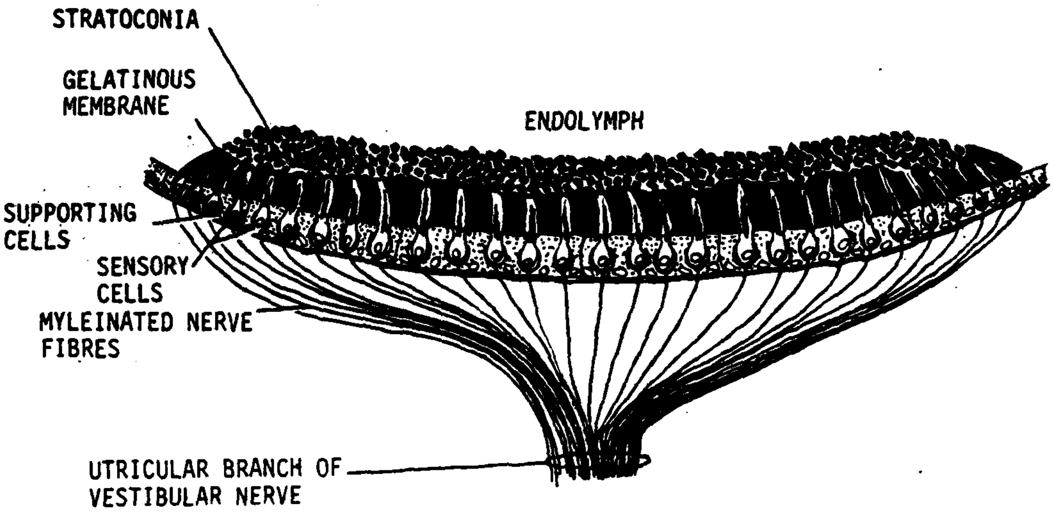


Figure 7-4 Sensing Stratoconia of the Utricle

it is likely that more than one element of the haptic system is receiving information relative to this movement. How this information is integrated is not known. One of the major difficulties in haptic system research is an inability to isolate each element during experiments. Some may be anesthetized and the remainder studies. This technique cannot be generally applied however.

7.2.2.3 The Visual Sensory System. Motion is perceived not only via mechanoreceptors but also by photoreceptors. In humans the photosensitive cells are of two types, rods and cones. These receptors are located in the eyes. The rods and cones are located in the retina. Each retina has a central (foveal) zone for detailed color and pattern vision, and a surrounding peripheral zone is sensitive only to the grosser features of the outer visual field. The fovea is close to the optical axis of the eye and is that portion of the retina where the inner layers of the retina are absent, thereby permitting an almost unrestricted flow of light to the receptors. The central fovea is characterized by densely packed cones. Toward the edge of the fovea, rods also appear, and as the distance from the center of the fovea is increased the ratio of rods to cones increases but the density of receptors decreases. This explains the lower threshold of perception in the fovea rather than in the periphery.

The discrimination of motion is greatest at the fovea but the appreciation of motion seems highest in the periphery. This essentially means that motion is detected in the periphery but the stimulus lacks information therefore motion acuity is greatest at the fovea.

7.2.2.4 Response of The Physiological Receptors. Now that the various physiological receptor systems have been functionally described, a discussion of their response characteristics is required. There has been a significant amount of research done on the thresholds of perception of these receptors. Some of the work dates back to the 19th century. However the single fact that has become the most obvious is that the range of thresholds of the population is fairly large and therefore averages are simply mathematical quantities which do not necessarily fit any individual. However, these averages can be useful tools in a cue coordination analysis. Table 7-2 presents a compendium of threshold of perception data for the vestibular, haptic and visual systems. This data reflects the results of many studies which attempted to answer this question, however each study essentially indicated need for further study. These thresholds are difficult to parameterize since they are multi parameter functions. There is a dependence on task loading, ambient conditions such as existing motion and duration and the natural variation among the population.

TABLE 7-2 THRESHOLDS OF PERCEPTION

MOTION

Semicircular Canals

$.5^{\circ}/sec^2$	Vertical	MEIRY 1965
$.14^{\circ}/sec^2$	Horizontal	MEIRY 1965
$.2-.5^{\circ}/sec^2$	Z Axis	JOHNSON 1959
$.41^{\circ}/sec^2$	X & Y Axes	STEWART 1970
$.67^{\circ}/sec^2$	Y Axis	STEWART 1970
$.2^{\circ}/sec^2$	Z Axis	TUMARKIN 1937
$.3-.5^{\circ}/sec^2$	All Axes	WENDT 1966
$.12-.15^{\circ}/sec^2$	Z Axis	CLARK & STEWART 1962
$.5^{\circ}/sec^2$	YAW	GROEN&JONGKEES 1948
$.06-0.35^{\circ}/sec^2$	Z Axis	MANN & RAY 1956

Otoliths

.005g	All Axes	GUM 1972
.02-.08g	All Axes	WENDT 1966
.01-.03g	Z Axis	GURNEE 1934
.03-.08g	Z Axis	FOGEL 1963
.08-.13g	X & Y Axes	FOGEL 1963

VISUAL

Fovea

1-2 min/sec	w/Ref	AUBERT 1886
10-20 min/sec	w/o Ref	AUBERT 1886
10 sec/sec - 40 min/sec		Injury Research Council

Periphery

18 min/sec @ 9°	w/Ref	OGLE 1962
180-360 min/sec	w/o Ref	OGLE 1962

THRESHOLDS ASSUMED FOR ANALYSIS

Semicircular Canals

$0.5^{\circ}/sec^2$

Otoliths

0.01g

Visual

10 min/sec

The frequency response of the vestibular and haptic system are given by Gum to be 0.1 Hz and 2 Hz respectively. Young indicates a 10 Hz response for the semicircular canals, but this is based on a velocity input and approximately 0.1 Hz for the otoliths. The frequency response data are primarily useful for determining the requirements for the simulator which will stimulate these receptors.

Another performance parameter of importance is the adaptation time of these receptors. According to Young, the semicircular canals have an adaptation time of 30 seconds, while the haptic system adapts in approximately 1.0 second. The rapid adaptation characteristics of the haptic system is no doubt why motion systems which use an onset cuing philosophy with subliminal washout seem feasible.

One further comment to conclude the discussion of the physiological aspects of motion sensitivity is the effect of the absence of any of these stimuli. For example, if there is no stimulation of the vestibular whatsoever or haptic systems, and only of the visual apparatus, will the crewman perceive motion correctly? It is thought not. This may be illustrated by the familiar railroad station paradox. That is the situation where a passenger in one railroad train thinks he is moving when he sees the train on an adjacent track move. However he is confused by this phenomenon because he did not "feel" motion; he only "saw" it. Of course in this situation there has been no vestibular or haptic stimulation. There are many levels of stimuli which may be considered in this type of discussion and some are far more subtle than the railroad station paradox. Some examples of these areas of uncertainty are: Is it necessary that the organ be stimulated at the correct magnitude or is it sufficient that the direction be correct, or can small components be left out? Consider the case of rotation. If the observer is situated some distance from the center of rotation there is a translational component associated with the rotation proportional to the radius of curvature. Therefore, the vestibular system senses the rotation via the semicircular canals and the translational component via the utricles. Clearly - if the radius of curvature is large, the utricular stimulation is important. However, other factors such as the task loading, the preexisting motion, the dynamics of the control loop, the absence or existence of disturbing influences, etc. are important. This discussion could continue for quite some length, but this is not intended to be a treatise on the perception of motion but rather a means of illustrating the complexity of the problem.

The foregoing indicates that for any different application, empirical methods should be used to determine which stimuli are necessary.

7.2.3 Motion Cue Analysis and Simulation Philosophy. In the previous section 7.2.1 and 7.2.2, tank kinetics, which influence

motion simulation were tabulated and discussed and the motion sensing physiological apparatus was explained. The objective of this section is to evaluate this data in order to establish a motion training requirements and motion simulation philosophy.

In section 7.2.1 data was tabulated separately for the driver station and the turret, the rationale being: it was considered that cuing requirements could be different for the two stations. This approach did not preclude the possibility of applying the same cuing to both the driver and the occupants of the turret. It became obvious, however, that unless the kinetic relationship between the hull and the turret could be maintained, separate cue sources would be required. The imposition of this requirement emanates from two major considerations:

1) The turret, being suspended within the hull, has different mechanical response characteristics than the hull.

2) As the turret slews, its occupants sense motion of the hull differently as a function of the turret deviation angle.

The first consideration is supported by the data; the second is a simple statement of fact. The second can be appreciated easily by the following example: consider the situation where a simulated tank is proceding due north with the main gun pointing due east. Motion cues, which to the driver are sensed as pitch, would be sensed as roll to the occupants of the turret facing in the same direction of the gun. It further follows that longitudinal motion to the driver would be lateral motion to the turret crew, etc. Of course non-orthogonal orientation of the turret relative to the tank requires combinations of degrees of freedom. The foregoing implies a requirement for continuous turret rotation capability in the simulator or separate crew stations for the driver and turret crew. That is: if onset cuing is used for turret rotation, separate crew stations must be used for the driver and the turret crew.

However, even if continuous turret rotation is provided, the correct driver-to-turret crew geometrical relationship must be maintained. Also, the simulated turret must be suspended in the simulated hull such that the structural coupling transmits the motion dynamics "similar to" the actual vehicle. The phrase "similar to" is obviously vague, but not intended to be deceptive. It is not known what effect on transfer of training a degradation of fidelity of cues in this area might have. However, some more conclusive statements may be made about this problem. First of all, consider the transmission of vibratory cues across the turret/hull structural interface. It can be shown that man is much more sensitive to the frequency and amplitude of a vibratory stimulus, than phase shift. Therefore, the important parameters to preserve are frequency and amplitude. The question now is: to what extent must

frequency and amplitude relationships be maintained? When a person's ability to estimate these parameters absolutely is low, he does possess capability for relativistic discrimination. That is, he might be able to say that a particular cue has a frequency which is too high or too low but is not able to quantify it as being 12 Hz instead of 13 Hz, for example, or 0.2 g instead of 0.3 g. But the actual thresholds cannot be absolutely quantified because they are a function of too many variables - ambient motion, task loading, intensity, etc. Therefore, a reasonable approach might be to incorporate sufficient flexibility into the laboratory model to vary the structural coupling between the turret and the hull in order that the actual requirements may be determined empirically. One method to implement this decoupling would be the incorporation of separate motion systems for the turret and the driver station.

To firmly establish requirements for turret rotation motion cuing, the first question which must be answered is: "Is any vestibular/haptic stimulation required to adequately simulate turret rotation or is it sufficient to provide motion cuing solely with visual and aural effects?" As was stated previously, the absence of stimuli to any of the physiological receptors may cause vertigo or motion sickness. However, how much kinesthetic cuing is actually required is a much more difficult question to answer. The cues could run the gamut from a jolt to indicate starting and stopping, to onset cuing, to full continuous turret rotation in replication of the real-world turret. The concept of onset cuing has been demonstrated to provide adequate stimulation for continuous rotation, particularly when no realignment of the gravity vector is required. Therefore the question reduces to whether a jolt would provide sufficient training value. It is felt that the only way to conclusively establish this is to have the capability for onset cuing available in the laboratory model and degrade it to a jolt for experimental purposes.

Pitch and roll are required at the turret to provide the cues associated with along- and cross-slope operations. It is further recommended that these 2 degrees-of-freedom be driven kinematically (platform angle proportional to tank angle) rather than employing an onset philosophy.

Longitudinal and lateral motion would be desirable to provide acceleration/deceleration cues as well as main gun firing effects, although pitch and roll may be substituted without significant loss of training value.

Heave is required at the turret to provide cues indicating rough terrain and vibration effects. The heave mode could also provide main gun safety stop bump. Therefore, definite requirements for 3 degrees of rotational freedom (pitch, roll and

turret rotation) and one translational (heave) have been established. A desirability for longitudinal and lateral motion has also been identified.

The degrees-of-freedom required for driver's station motion are pitch and roll, driven kinematically, to provide cues of slope operations; longitudinal, to provide acceleration and deceleration cues; and heave, for vibration and bounce. Either lateral or yaw would be a sueful adjunct for turret start/stop transients, and if available on the simulator, could be used to investigate the usefulness of either degree-of-freedom for turning cues.

Table 7-3 summarizes the requirements for driver and turret crew members. These data constitute the performance requirements in each degree-of-freedom, in terms of displacement, velocity, and acceleration. Also tabulated are the vibration requirements listed as frequency and amplitude. The table is configured to illustrate which degrees of freedom are considered to be necessary or useful. The absence of an entry (-), implies no requirement. These requirements were derived from an analysis of the tank data in section 7.2.1 and the discussion in 7.2.2.

In general, the table implies full fidelity simulation and does not consider limitations due to cost and other factors. Pitch and roll for both stations was considered to be driven kinematically with the constant of proportionality equal to unity. Velocity and acceleration requirements are a result of subjecting the commanded angle to linear second order cue shaping.

Yaw is not considered essential at the driver's station but is used to provide onset cues of turret rotation at the fighting station. Since the semicircular canals are sensitive primarily to rotational velocity, it is desirable to provide the stimuli associated with turret rotation by means of a position proportional to the velocity drive signal. Therefore, to provide the full velocity capability of the turret a platform yaw rate of 0.39 rad/sec is required. The excursion and accelerations presented in table 7-3 are the result of the second order cue shaping dynamics.

Translational cues (longitudinal, lateral, and vertical) result from stimulation of the utricles and are therefore acceleration sensitive. The appropriate drive concept for these 3 degrees-of-freedom would be a position proportional to acceleration approach. For full acceleration stimulus, the constant of proportionality is chosen such that the platform acceleration equals vehicle acceleration. The excursion and velocity shown in the table are the result of employing the second order cue shaping dynamics. Longitudinal and vertical cues are required at both crew stations. Lateral

TABLE 7-3 MOTION EXCURSIONS AND ACCELERATIONS

Degree of Freedom	Mode	MOTION REQUIREMENTS			
		HULL		TURRET	
		Required	Useful	Required	Useful
PITCH	DISP. VEL. ACC.	±0.64 rad ±1.11 rad/sec ±17.3 rad/sec^2	-	±0.64 rad ±1.11 rad/sec ±17.3 rad/sec^2	-
ROLL	DISP. VEL. ACC.	±0.3 rad ±0.52 rad/sec ±8.11 rad/sec	-	±0.3 rad ±0.52 rad/sec ±8.11 rad/sec^2	-
YAW	DISP. VEL. ACC.	- - -	- - -	±0.23 rad ±0.39 rad/sec ±6.12 rad/sec^2	-
LONGITUDINAL	DISP. VEL. ACC.	±10 in ±15 in/sec ±0.6g	-	±10.0 in ±15 in/sec ±0.6g	-
LATERAL	DISP. VEL. ACC.	-	±10 in ±15 in/sec ±0.6g	±10.0 in ±15 in/sec ±0.6g	-
VERTICAL	DISP. VEL. ACC.	±15 in ±25 in/sec ±1.0g	-	±15 in ±25 in/sec ±1.0g	-
VIBRATION	FREQ. AMPLITUDE	30 HZ 0.03g	-	5HZ 15 HZ 1.0g 0.05g	-

cues are of limited value at the driving station. It is, however, required at the fighting station if continuous turret rotation is not provided.

Finally, during analysis of vibration requirements, it became evident that while there are measurable vibrations in the orthogonal directions and at several harmonies of 5 Hz, not all are significant. The amplitudes, as indicated both in terms of acceleration and power spectrum analysis, are small in the lateral and longitudinal direction as compared to the vertical. Also, frequencies other than 5 Hz and 15 Hz also produce low amplitudes at the fighting station.

The only vibration data available for the driver's station indicates that a relatively high frequency, low amplitude signal is required in the veritcal direction.

7.3 Crew Station Simulation Requirements

Interactive crew training must include each individual task associated with operating the M60A3 in a combat environment and normally performed at the crew stations. These tasks will be coordinated to permit the crew to develop skills in working together and reacting to the variety of problems they could expect to encounter in combat. Accurate representation of each crew station and system functional characteristic is important in establishing a context for crew interaction.

7.3.1 Tank Commander Station. The tank commander's station must include the gear used by the commander in closed-hatch, popped-hatch and open-hatch operations as well as controls for moving the turret, main gun, and cupola. The commander must have access to the .50 caliber machine gun so that he can clear, load, fire the gun, and replenish ammunition if necessary. The commander must also be provided with the optics, controls and scenes associated with his periscope and the laser rangefinder and thermal sighting system (including reticles and readouts used in sighting, aiming and ranging). Intercom and radio controls are also required, to permit communications within the tank, and between the tank and other tactical elements.

Rotation of the commander's cupola must be simulated to permit the commander to employ the .50 caliber machine gun in the closed-hatch or head-up position. The cupola locks and the designate switch must be operable to allow him to fire the main gun and coax machine gun from his position. Connections to the gas particulate system are also required, to simulate NBC operations.

The commander searches his area with unaided vision, powered optics, and thermal sights. In button-up operations, he also uses these systems together with vision blocks. The commander must also have the use of hand-held binoculars to permit him to search rapidly and efficiently in open-hatch operations, where the situation changes rapidly, and threats may be visible in many different sectors.

7.3.2 <u>Gunner Station</u>. The gunner's station must include a unity-power periscope, telescope, powered periscope, and thermal sight including appropriate reticles and controls. The gunner's quadrant, elevation quadrant, and azimuth indicator are also required. The gunner must have operational gun controls and stabilization switches, manual and power turret and gun controls, and controls and displays associated with the ballistic computer.

The gunner's manual turret controls must reflect friction present in the real system, so that when power is not available, the gunner experiences realistic feel when exercising manual control over turret rotation and gun elevation and depression.

The gunner also needs an intercom with controls, and connections, and a connection to the gas particulate system.

7.3.3 Loader Station. The loader's station must include the loader's seat, hatch and hatch cover, and the loader's periscope. The periscope, and the open hatch must permit the loader to view the visual scene. The loader's station must also include ammunition ready racks, stowage, and ammunition representing loads for typical missions, for both the main gun and the coaxial machine gun. The main gun breech and the coax must also be present and operating, but the coaxial machine gun need not require maintenance other than immediate action. The coax ammunition box must deplete proportionally to coax firing, forcing the loader to monitor and replenish. Main gun rounds must be accurate as to size, shape, weight, and color coding, to provide realism when selecting and loading main gun ammunition under stress and time pressure of combat. The simulated APERS round must have a settable fuse. The empty casing of each round fired must be ejected onto the floor of the turret. This function helps the loader learn to operate with shell casings on the floor, and to stow them temporarily until it is possible to eject them from the turret.

The loader must be able to open and close the main gun breech, to remove rounds already loaded. This will give the rest of the crew experience in working around necessary delays in main gun operation (as would occasionally be required in combat).

The main gun breech must recoil during simulated firing, to prevent the loader from developing unsafe habits. The breech should not move rapidly enough to injure the loader, but should discourage him from allowing himself to be struck. It is not expected that loaders will learn loading fundamentals in the FCIS, but the system must simulate the loader's environment realistically enough to permit him to form safe and effective habits relevant to rapid, sustained fire. Intercom and breathing connections are also required at the loaders station. The loader's machine gun must also be provided.

7.3.4 Driver Station. The driver's station must include all of the driver's controls and instruments, his vision blocks, hatch, and image intensifier systems. The simulated engine, transmission,and track must respond to control inputs as they would in the tank. The drain valve control must operate as it does in the tank, but need not involve flooding of the driver's compartment when fording. An indicator can be used at the instructor/operator station so that the driver can be alerted when he fords with the valve open.

Engine fire extinguishers are required at the driver's station, with appropriate indicator and reset capabilities at the instructor/operator station. Intercom and gas particulate system connections and controls are also required.

7.4 Vehicle Systems Simulation Requirements

Most of the tank's systems are directly or indirectly controlled by the crew, and provide task information to the crew by way of indicators and displays, sounds, vibrations, motions, and other stimuli. In some cases, one system may influence the information derived from another. Smoke produced by the main gun provides little useful information to the crew, but strangely, influences the crew's use of its vision devices. The performance of each system having an effect, either directly or indirectly, on critical crew tasks, must be simulated to permit practice of important crew interaction tasks.

It is frequently necessary for the commander and the gunner, and always for the driver, to know something about the performance of automotive systems. The commander, hearing the engine strain or the track vibrate, knows how much more speed or maneuverability he can ask for. The gunner has little need for this information, but will occasionally adjust his performance to adapt to the tank's ability to turn or accelerate. The effects of acceleration, turns, and braking on the loader can make his jobs extremely difficult and hazardous. The sounds, vibrations, and motions associated with the automotive systems are important in training the gunner to anticipate and cope with disturbances due to tank motion.

Performance of automotive systems is important to the driver in that it determines the degree of control over speed, acceleration, stability and maneuvering he can exercise. Sounds of the track are important as it moves over various kinds of terrain, in telling the driver something about the effect his performance is having in the turret. Vibrations produced by rough terrain, and by track interactions with the terrain at various speeds are much more pronounced and debilitating in the turret than at the driver's station. As a result, sounds heard at the driver's station which accompany disturbances in the turret are important in helping the driver to judge his performance as it relates to the needs of the turret crew.

The crew will have learned most of the skills and procedures required to operate the tank and its systems, before being trained in the FCIS. They will also have learned procedures required to correct or compensate for system malfunctions. Training in the FCIS will be their first opportunity to learn, as a crew, to work around system failures to complete their assigned missions. Failures of major automotive systems are required to provide the tank commander with opportunities to reassess the situation, and to develop and practice courses of action necessary for the completion of the mission. Automotive system failures are also required to permit the driver to practice diagnostic and corrective procedures under the pressures imposed by a tactical situation. In some cases, he will

also have to make decisions about how to modify his performance to compensate for the failure of the transmission or track.

7.5 Weapons Systems Simulation Requirements

Integrated crew operations involve firing the main and coaxial guns from the gunner and commander's stations, the commander's .50 caliber machine gun, the smoke grenade launchers,and the loader's machine gun. The firing of each weapon system must be simulated to provide the information used by the crew in threat engagement, and to provide the workload needed to train effective crew interaction.

7.5.1 Main Gun. Main gun sound and recoil must be simulated with sufficient realism to provide the training value required with full consideration of crew safety. The sound of the main gun is important to the entire crew as an indication that the gun has been fired, and in training the crew to rely on standard procedures and the intercom for interaction, rather than on unaided voice communications. The sound is also important in preparing the crew for the real tank environment. Recoil is important primarily to the loader, who must learn to work rapidly around the breech of the gun, while avoiding contact with it. Empty shell casings must be extracted and ejected from the gun to permit the loader to develop techniques for maintaining high rates of fire without losing his balance on the moving, unsteady turret floor. The breechblock of the main gun must be realistically simulated to force the loader to employ valid loading techniques. Main gun ammunition must be the same size, weight, and shape and generate the same impact effects as rounds carried in combat.

It should be possible to boresight and zero the main gun, but boresighting the main gun can be readily practiced on the operational tank (giving it low priority on the FCIS).

Main gun malfunctions must be simulated, to force the crew to apply immediate corrective action procedures, and to practice unloading the main gun. Main gun failures are also necessary to force the crew to develop and employ new sources of action in accomplishing the assigned mission and in maintaining the security of the tank.

7.5.2 Coaxial Machinegun. The coaxial machine gun and its fire must be separated, as a part of the gunner's and the loader's responsibilities. Coax malfunctions must be simulated, but need not involve extensive loader diagnosis and corrective action. Depletion of coax ammunition must be simulated, since one of loader's primary responsibilities is monitoring and maintaining the ammunition supply. The sound of the coax gun is important as it provides feedback to the gunner, tank commander, and driver, and helps the loader keep track of expended ammunition. Simulation of coax noise need not

represent unique sounds associated with various stoppages and failures, in the context of full crew interaction training. Depletion of the coax ammunition belt and simple stoppages must be simulated to give the crew practice in revising its methods of engagement accordingly. When stoppages can be cleared, the crew may wait, or the commander may decide to use the .50 caliber machine gun or an APERS round; or he may decide to direct the driver to change routes or move to another position, depending on the situation at the time. Coax tracers and tracer burnouts must be simulated. Ricochets from hard targets must also be simulated to provide information about the nature of concealed targets in reconnaissance-by-fire procedures.

7.5.3 Loader's Weapons. The loader's 7.62 machine gun, stowed in the turret, must be able to be mounted outside the hatch and fired at targets in the loader's field of view. Tracers and tracer burnout at realistic ranges must be simulated. When the gun is fired at hard targets, ricochets must also be simulated, whether the target is in the open or concealed behind vegetation.

The loader must be able to load, charge and clear the machinegun; but only simple stoppages need be simulated. It is not necessary to simulate burst cartridge cases, since these stoppages require more complex corrective action than is necessary for integrated crew training. The sounds of the loader's weapon must be simulated, to alert the rest of the crew to the fact that it is being employed, or that it has stopped.

7.5.4 .50 Caliber Machinegun. The commander's machinegun must be simulated to include loading, changing and clearing, ammunition depletion, tracer burnout, ricochets, and simple stoppages. The commander should be able to attach a new ammunition belt to the belt remaining in the ammunition box. A simpler indication of ammunition depletion could be used, inside the box; the commander should have to open the box to see the amount of ammunition remaining. Sounds of the gun must be simulated, to inform the rest of the crew, especially the driver, that the gun is being fired, or that it has stopped firing.

7.5.5 Grenade Launchers. Smoke grenades must be simulated to permit the commander to simulate screening the tank. Smoke produced by the grenades should range in density from transparent to opaque, and it must drift with the wind, to force the commander and the driver to compensate for drift by planning and changing routes. Smoke should become transparent with time, but for purposes of crew interaction, may simply diminish in size and disappear.

7.5.6 Personal Weapons. The crew's personal weapons and the .45 caliber ammunition stowed in the turret are not relevant to crew interaction training, except in practicing pre-operational

equipment checks. Each member of the crew will have been trained in maintaining and firing his personal weapon; no further training is required in the FCIS.

The turret should be marked to indicate the stowage area for .45 caliber ammunition, and for other supplies not needed in integrated crew training, but the ammunition and supplies need not be simulated.

The main gun, the coax and the .50 caliber machinegun, and the associated fire control instruments must include controls for boresighting and zeroing. Some steps in boresighting can be simulated, to minimize system cost. It is not necessary for the crew to attach cross-threads to the main gun nozzle, but the crew should be able to zero the guns by firing at a zeroing target, and adjusting sight reticles into the shot groups. Ammunition dispersion must be simulated for each weapon and ammunition type to prevent identical impacts from identical lays.

7.6 Instructional Systems Requirements

The special characteristics of a laboratory model training system require both instructor and manual control of every facet of cueing, monitoring, and evaluation systems. Cueing systems should either duplicate the real world or incorporate sufficient flexibility to allow cues to be broken down to their basic components to determine what information is required to bring the student to criterion. The instructor should be able to automate his cue presentation sufficiently to allow him to observe crew actions and end results in real time, and evaluate performance to the degree that will permit him to initiate appropriate performance data selection for student feedback and critique.

The FCIS instructor should have controls and color alphanumeric and tactical map displays together with visual repeaters or a direct visual scene view to perform the following functions:

a. Observe crew action and view the entire tactical scene both as the crew sees it and also as a symbolic tactical map. This would allow the instructor to evaluate their scanning and sighting patterns and techniques, and to selectively control and alter the tactical situation. Direct view of the visual scene and the crew is preferable to the use of visual repeaters, in that subtle crew actions, intra-crew coordination and crew/visual coordination may be accurately observed, modified and evaluated, without the spatial distortions, data integration and timing problems inherent in remote monitoring and control systems.

b. Monitor a master index of all alphanumeric/map display functions and capabilities.

c. Control initial conditions:

1) Modify or build initial conditions, including simulated own tank position, orientation; Geographical terrain; Environmental situations; Weather; Threat and friendly forces, (type, distribution, and quantity).

2) Review all initial conditions.

3) Insert selected initial conditions.

d. Control current conditions:

1) Monitor current conditions.

2) Freeze selected parameters.

3) Modify selected tank, environmental, visual, and tactical conditions.

e. Control malfunctions:

1) Review malfunctions by system.

2) Insert malfunctions.

3) Delete malfunctions.

4) Delete all active malfunctions.

5) Monitor all active malfunctions by number and description.

6) Inhibit pre-programmed malfunctions,

f. Control tactical situation:

1) Select weapon malfunctions.

2) Display and control threat and friendly locations, type, dynamics, firing, and reaction to the FCTS (manually or automatically).

3) Select target to be engaged or target sequence.

4) View map, visual, and alphanumeric/graphic displays of gunnery performance.

h. Generate hardcopy:

1) Store "snapshots" of the alphanumeric/map CRT display.

j. Control map displays:

   1) Display appropriately scaled tactical contour maps with own tank and threat track.

   2) Erase ground track.

k. Reverse/Advance Multiple Page CRT Displays (e.g., malfunctions)

   1) Data Clear - Clear all data accumulated during a previous training session and reinitialize to a clean condition.

m. Freeze the entire training problem and monitor when a freeze condition exists.

n. Monitor all weapons system, vehicle control system, and sighting system control status.

o. Select emergency shutoff of all electrical power to the entire complex.

p. Monitor selected parameters and instrument and control readings and positions.

q. Monitor time of day, mission elapsed time and stopwatch timer time.

r. Select demonstrations, preprogrammed test exercises, or record/playback sections.

During high density tactical operations, the instructor(s) must also be capable of performing the following functions.

s. Monitor, analyze and evaluate individual crewmember's actions and reactions (including normal and emergency procedures and a variety of intracrew and intercrew reactions to a variety of terrain and threat stimuli).

t. Monitor, analyze and evaluate coordinated crew actions and reactions (including normal and emergency procedures and a variety of friendly force, terrain, and threat force stimuli)

u. Adaptively vary the tactical environment to tax the crew without overwhelming them, to locate and eliminate individual of crew weaknesses.

   The following are required:

   - Capability to observe and identify any weak point in individual or crew actions.

- Knowledge of type and location (including when detection and kill positions are reached) of all friendly and threat forces.

- Capability to coordinate friendly and armor and artillery fire.

- Capability to use visual scene and dynamic tactical maps to determine best routes, best firing positions, best offensive and defensive actions and reactions from which to evaluate and modify crew headwork and actions.

v. Control the visual system including on/off,resolution, field of view, brightness, tactical feedback (threat, detectability and visual sensing) and scene complexity (number and detail of features).

w. Motion ON/OFF.

x. Appropriate controls and displays to allow the instructor(s) to act as any one, two, or three members of the crew.

The Tank Commander/Driver observers require the following control and display capabilities.

a. Emergency stop control

b. Motion ON

c. Motion OFF

d. Freeze control/indicator

e. Visual controls

f. A tactical map (selectable by the instructor) providing location and type of all friendly and threat forces.

g. Problem setup initialization,demonstration, and playback controls.

7.7 Visual/Motion/Instrumentation Synchronization

The dynamics of the tank, its unique transmission, and steering and braking systems must be reflected in the driver's instruments and in the sound of motion and vibration at each crew station. Although the driver makes relatively little use of his instruments, tachometer and speedometer indications must correlate with accelerator, brake, and gear shift positions. Sounds associated with movement of the track over various kinds of terrain and the speed relative to accelerator position must vary realistically, to permit the driver, and the other members of the crew to review speed and to perform accordingly.

Sound and vibration are different at the driver's station than they are in the turret, because of the distances between crew stations, sources of sound and vibrations, and the different resonances influencing them. These differences must be simulated, particularly to keep the driver aware of the severity of vibrations in the turret which he does not directly experience.

Motion of the crew stations and the visual scene dynamics observed by the crew must be represented. Although actual motion excursions in the simulator need not duplicate the tank motion being represented, visual scene dynamics must accurately represent the motion of the tank, turret, and cupola. Full rotation of the turret is not required, except from the visual aspect. Onset turret rotation motions are required, however, to alert the turret crew to the direction and magnitude of motions to be experienced. All motions, sounds, and vibrations must be synchronized with the visual scene to prevent delays in tracking the visual scene from the fire control instruments and the driver's station, and to minimize vertigo in going from the tank to the simulator, and from the simulator to the tank. Since motion is sensed by the vestibular and haptic systems as acceleration and velocity, and by the visual apparatus as change in position, then at the threshold of perception of these various systems, force and motion cues should precede visual cues.

The preceding indicates the proper sequence of cue occurrence. But what about maximum time delays from initiation of a maneuver until cue sensation, or maximum missynchronization among the various cues? Little data is available quantifying these parameters. A recent study by Miller & Riley indicates no increase in tracking error until the overall delay was 250 ms and 375 ms, depending on the simulated vehicle's control characteristics.

Whether these results can be applied to the simulation of the M60A3 is not completely certain. What can be said is that delays can be longer in any simulation that has a "looser" control loop. By that it is meant that if the environment/man/vehicle control loop has a naturally longer effective time constant then longer delays may be tolerated. However, the proper sequencing must be maintained.

Motion and visual cues should, however, be synchronized to within less than 150 milliseconds to prevent crews from developing simulator-specific tracking skills, especially when firing on moving targets, or when firing on the move.